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J. Ashburton Thompson

EIGHTH ANNUAL REPORT

OF

THE LOCAL GOVERNMENT BOARD

1878–79.

SUPPLEMENT

CONTAINING THE

REPORT OF THE MEDICAL OFFICER

For 1878.

Presented to both Houses of Parliament by Command of Her Majesty.

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PUBLIC HEALTH.

ANNUAL REPORT

OF THE

MEDICAL OFFICER

OF

THE LOCAL GOVERNMENT BOARD

FOR THE YEAR

1878.

CONTENTS.

REPORT.

TO THE RIGHT HONOURABLE GEORGE SCLATER BOOTH, M.P., PRESIDENT OF THE LOCAL GOVERNMENT BOARD, &c.

SIR,

IN supplement to the Board's Eighth Annual Report, the Medical Officer, Dr. Seaton, proposed to lay before you his Report upon the work done through his department in the year 1878 in matters concerning the public health. He was unhappily prevented by illness from fulfilling this intention, but the materials which he had prepared enable me to submit to you the following statement of proceedings during that year. MEDICAL OFFICER'S REPORT.

Vaccination.

I. (*a.*) The inspection of public vaccination and the supervision of the working of the Vaccination Acts engaged as usual much of the time of the Department. In a first Appendix to this Report will be found a digest of Vaccination Officers' Returns, showing continued successful working of the Vaccination Acts; with improvement that is satisfactory to note in the returns for the metropolis. Between 1875 and 1876 the per-centage of children born in the metropolis and not finally accounted for as to their vaccination at the date of the several returns, underwent an important reduction. In the earlier year this percentage was 9·3, in the later year 6·5; the latter figure still indicating, however, an inferior degree of completeness in the metropolis as compared with other parts of the kingdom. The difference may be either in the amount of infantile vaccination or in the recording of such vaccination, or partly in one and partly in the other. The significance of the apparent shortcomings in the metropolitan returns is being investigated in the Department.

In a second Appendix is a list of 276 unions, in which the working of actual arrangements for public vaccination was investigated in detail by Inspectors of the Department during 1878. From this and from the corresponding tables of former reports, the satisfactory result may be gathered, that obedience to instructions designed to promote efficiency and safety of vaccination, and, with that obedience, the proportion of first-class vaccination, have progressively increased. At the present time public vaccination is found to be of first-rate excellence in 74 per cent. of the vaccination districts visited, while awards of money from the Parliamentary grant are made to 51 per cent. of the public vaccinators whose work is examined These awards,

representing completeness of observance of contract duties as well as first-class quality of vaccination, have been earned, it is satisfactory to note, by twice as many public vaccinators during 1878 as during 1872.

(*b*.) The Department continued during the year 1878 the administration of the National Vaccine Establishment. In compliance with your desire, I describe the operations of the establishment with somewhat more than usual detail, although there has been nothing exceptional in the year's work. The stations from which lymph is supplied to the establishment have, as usual, been visited systematically by Dr. Stevens. They have been found in excellent working order, and the vaccinators in charge of them have been found careful in the selection of lymph and in the processes required for its preservation. Furthermore, in accordance with now established practice, the lymph has been subjected, after its receipt at the office, to exact microscopical examination, with the result of eliminating a certain proportion of the supply which has appeared on one ground or another to be undesirable for distribution.

Charges of lymph have been distributed from the Establishment to 9,590 applicants, being public vaccinators, private medical practitioners, and others described in Appendix No. 3. From those who have used the lymph, representations as to want of success with it have been received from less than four per cent.* Complaint of some untoward result attending the use of the lymph has been made by six out of the 9,590 recipients of the lymph. Each of these complaints has, according to the custom of the Department, been the subject of special inquiry. In one instance erysipelas had followed vaccination with the lymph; the evidence, however, did not point to the lymph as the cause of the erysipelas but suggested exposure to some local infection during the progress of the vaccination. In the remaining instances, where the complaint related to some irregularity in the course of the vaccination, inquiry was made as to other children who had been vaccinated with the same lymph, and in no instance did it appear that similar irregularity of result had been witnessed in the other children. Hence a strong presumption arose that the irregularity (which in no instance was a matter of serious importance to the health of the child vaccinated), was related rather to the previous state of health of the individual upon whom the operation was performed than to any peculiarity of the lymph distributed from the Establishment.

No hint of a case of syphilitic disease connected with vaccination was heard of from any one of the 9,590 medical practitioners to whom the lymph was supplied.

(*c*.) The Medical Department was engaged during the year in the consideration of two questions relating to Animal Vaccination, the one pathological, the other administrative.

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* These were, of course, failures with *preserved* lymph.

(1.) Dr. Klein was occupied at the Brown Institution, under the supervision of the Medical Officer, of Dr. Burdon Sanderson, and of Mr. Ceely of Aylesbury, in certain experiments which had for their object to settle a disputed point in the pathology of vaccinia; namely, whether or not it can be produced in bovine animals by inoculation of them with the lymph of human small-pox. At the end of the year Dr. Klein had obtained no affirmative result; though his operations had extended to the inoculation of 16 heifers and 15 milch cows; and though the lymph he used had been taken from cases of small-pox at various stages of the disease. It is intended, if opportunity serve, to continue the experiments further, and for the present it is not proposed to publish the details of the observations.

(2.) The Medical Officer in person made inquiry, during the autumn of 1878, into the use of vaccine lymph cultivated upon calves and employed in human vaccination at certain stations on the continent. From a memorandum which he prepared, but which is not a complete report on the subject, it appears that the difficulties which had at first been encountered in the transmission from animal to animal of lymph derived in the first instance from a natural source of cow-pox had practically ceased. Dr. Seaton was able to observe a considerable number of children upon whom vaccination had been performed with lymph taken direct from the calf after long transmission through the calf system, and he says of them that their vesicles were neither more nor less complete, though somewhat smaller in size, than the vesicles produced by like methods of operating with humanized lymph at the public vaccination stations of England. The chief difference between the two lymphs was in the degree of certainty with which a desired result could be produced. In the hands of an experienced operator with fresh *humanized* lymph in England, 2,996 children out of 3,000 were successfully vaccinated at the first attempt; and failure to produce a vesicle where it was intended to produce a vesicle occurred so rarely that, with a fair approach to certainty, every child obtained the whole result which the operation was intended to produce. On the other hand, according to Dr. Seaton's observations at Amsterdam and the Hague, vaccination done by very experienced operators, but with fresh *animal* lymph, showed two total failures out of 91 operations, and 20 cases out of the 91 where the number of vesicles had been less than half the number that the operator had endeavoured to produce. At Rotterdam complete success had been attained in only some 54 per cent. of children operated on. At Berlin 7 per cent. of total failures were recorded; and of the successful operations, complete success had been attained in much less than half of the children operated on. These failures to obtain complete results had in Berlin led to a large proportion of the children receiving an imperfect degree of protection against small-pox, and at Amsterdam and the Hague had led to the practice of making a much larger number of insertions than were regarded as necessary for pro-

tection against small-pox, merely because the operator expected that some of the insertions would fail.*

The following paragraphs from Dr. Seaton's memorandum bring into relief certain considerations that are often overlooked by those who have not studied the working of the English system, and who believe that England has only to follow the experience of Belgium to exchange her own excellent system for a better :—

" Anyone who is familiar with the practice of public vaccination in England will at once see the difficulties which would be met with in inducing parents first to allow their children to be submitted to 10 punctures, instead of the 4, 5, or 6 which are usually employed in this country, and which under the use of the current lymph are quite sufficient to secure the number of vesicles desired, and secondly to allow the performance in a considerable number of the cases of a second vaccination at the end of the day week, even supposing that this second vaccination could be relied on to make good what had been wanting in the first. It was the great object, steadily held in view, in the re-organization of the public arrangements for vaccination in England, that these should be such as would make the single performance of the operation as completely successful as in the nature of things a single infantine vaccination can be. " * * *

" From these notes respecting the success of animal vaccination in those countries of Europe in which I was able to inspect it on the present occasion, it will be seen how considerably inferior are its merits for effectually producing at once the needful protection against small-pox to that of the system at present in use in England. The substitution of certainty for uncertainty of success in the performance of vaccination was the great purpose of the re-organization of vaccination arrangements which took place in England, in consequence of the official inquiry in 1859–64, into the then state of vaccination in this country, a re-organization which had been and is working with the most satisfactory results. To admit into our system, and stamp with the sanction of Government as one of equal value, a plan to which the main objection is its uncertainty, would seem to me to be indeed an inconsistent and a retrograde step. " * * *

" The practice of vaccination in Belgium does not, as might have been supposed from the statements often made, afford to the observer much opportunity of seeing for himself the direct action of animal lymph on the human subject, and of noting for himself its relative degree of success. Vaccination from the calf to the human subject was practised many years ago at Brussels at the Institut Vaccinal de l'État, as stated by me in my report for 1869 [12th Report of Medical Officer of Privy Council]; but this has long been discontinued, and the vaccination generally

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* In this paragraph, vaccination with *absolutely fresh* lymph is alone spoken of. At Berlin, record had been kept (Klin. Wochenschr. 1878, No. 16), of the result of vaccinations with animal lymph that had been stored. Of such vaccinations, 18 out of 60, or 30 per cent., had been unsuccessful.

in the kingdom is carried on by vaccinators, public and private, from arm to arm. It is absurd therefore to speak, as is sometimes done, of vaccination from the calf to the arm as the Belgian National System."

Thus the Department, in its concern with vaccination during 1878, was not content to know that the established arm-to-arm system was working extremely well and always with some improvement, but it was desirous of getting such information as it could obtain respecting the specialities and actual working of animal vaccination. The Department proposes, as occasion serves, to continue its researches in this direction. Opportunity for observing vaccinia in animals and the results of calf-vaccination on the human subject are not largely to be met with in England, and special arrangements for the further study of the subject in its various aspects may probably prove to be desirable. Meanwhile private establishments for the vaccination of children with animal lymph (if they should grow in this country, as they have grown in other countries, owing to some general demand for such lymph), can afford some of the opportunities of which the Department is in search.

Reports by Medical Officers of Health.

II. During 1878, as in other recent years, much time and labour was given in the Medical Department to a critical reading of reports, annual and special, by local Medical Officers of Health. These reports have enabled a fair judgment to be formed, first, of the ability of particular Officers of Health and of their devotion to their duties, and secondly, of the extent of sanitary operations in various districts. Many Medical Officers of Health, as well among those acting for combined districts as among those acting for separate districts or divisions of districts, and including Officers of Health for both large and small areas, have shown themselves actively and intelligently inquiring into the sanitary circumstances of their districts, and into the conditions of disease prevalent therein; and their reports and advice on these subjects have been of a character to deserve the fullest confidence of Sanitary Authorities and to serve as guides in efficient local administration, while informing the inhabitants of the districts of facts that ought, in the interests of health, to be known and acted on by them. At the other extreme, reports have been received that are quite perfunctory and without value, giving no evidence of knowledge of sanitary science or of acquaintance with the sanitary wants of the districts. So, with the sanitary work by the authorities of the various localities, when the report of the Medical Officer of Health has enabled an opinion to be formed on the subject, some Authorities have been shown to be doing their best to promote the sanitary welfare of their districts, while others have appeared to be careless or daunted by the first difficulty that has presented itself. The total impression left by the reports of the year 1878 as compared

with those of preceding years is, it is satisfactory to note, that Officers of Health and the Authorities whom they serve are alike becoming more appreciative of their sanitary functions, and various collateral circumstances confirm this opinion.

The Department has of course very limited opportunities of judging as to sanitary progress in those districts from which insufficient reports by Medical Officers of Health are received; but so far as its independent opportunities have gone, they have not infrequently tended to show a relation between unsatisfactory execution of the functions devolving upon Medical Officers of Health and shortcomings in the performance of sanitary duties by the Authorities.

Local Inquiries as to Prevalence of Disease.

III. Inquiry by the Board's Medical Inspectors into exceptional prevalences of disease has been made during the year in 14 instances, and has extended to the districts of 30 sanitary authorities. The most extensive of these inquiries has had reference to the Dewsbury Registration District, where 14 sanitary jurisdictions came under review.

Occasion for the several inquiries arose, in part, out of the quarterly returns of mortality published by the Registrar General; in part out of local representations and complaints. The reports of Inspectors on both classes of inquiry disclosed not a few examples of neglect by sanitary authorities to discharge their functions; but an increased appreciation of their duty in this respect has been often apparent since the Inspector's visit.

Two reports were of exceptional interest; one, that will be found appended to this report (Appendix, No. 5) related to a strange and fatal outbreak of skin disease among infants at Loughton, in Essex, that proved to be due to the presence of arsenic in the "violet powder" used for nursery purposes. The other had reference to an exceptional prevalence of diphtheria in districts of North London, where the disease was eventually traced to a particular milk-supply. This latter report has been printed as a Parliamentary Paper (No. 99 of Session 1879).

Effluvium Nuisances.

IV. The inquiry as to effluvium nuisances arising in connexion with various industries, upon which Dr. Ballard has been engaged since November 1875, not without many intermissions, has now been brought to an end; and the third and concluding portion of his report is appended. (Appendix, No. 6.) In former portions, industrial processes that are concerned with animals, animal substances, and with vegetable substances, have been considered; and in the present portion an account is given of various offensive processes wherein mineral substances are principally concerned, and of others wherein materials of mixed origin (animal, vegetable, and mineral) are dealt with. The governing idea of the inquiry has been to study "effluvium

nuisances" in their relation to the health of the *community;* and thus their influence within workplaces upon persons voluntarily subjecting themselves to such nuisance has been studied chiefly as it might throw light on the nature or circumstances of the influence which the nuisance could exert upon the outside community. For this reason, among others, trades injurious to workmen by reason of dust in the workplace have here been but little considered; they were the subject of special report to the Department in 1860–61. In the course of Dr. Ballard's inquiry some 70 different kinds of businesses, represented by 850 separate trade establishments in various parts of the United Kingdom, have been investigated; and it is probable that few offensive trades of any importance have been omitted. In the account of them considerable technical accuracy has been secured through the willing and active co-operation of manufacturers.

The object of Dr. Ballard's inquiry has been two-fold: first, to learn the extent to which the public health is injured by one or another offensive trade or trade process, under one or another condition; and secondly, to ascertain in what measure and under what circumstances nuisance and injury to health can be avoided.

In the study of the former problem, it has been impracticable from any available data during the time at Dr. Ballard's disposal to apply the numerical method to the differential investigation of sickness or mortality as influenced by proximity to offensive trade establishments; and the only method open to him has consisted in applying his own experience as a physician and sanitary observer to the estimation and interpretation of the health-state of people exposed to one or another influence; and in gathering up like estimates from the experience of other medical practitioners, notably of medical officers of health, whose judgment was entitled to respect. The resulting conclusions announced by Dr. Ballard rest then on a broad basis of careful observation by those whose opportunities have been of the best; and, while they constitute a valuable point of departure for further more detailed inquiries, his conclusions form by themselves an important increment to our previous knowledge of the subject.

The general result amounts to this: There are first a variety of influences upon health exerted by offensive trade processes, which have the specialty of being not offensive only, but concerned with definably infectious materials, or with poisonous materials in quantity, and are thus specifically infectious or poisonous to workers or to neighbours. Thus, danger from infective matter arises in the case of trades that deal with old wearing apparel and with foul house-refuse. So again (to take an instance where the offence was a matter of second rank) the manipulation of horse-hair infected with the contagium of anthrax has been found to be attended with serious and specific risks. For an important and elaborate communication on this particular subject, referring some recent occurrences in Glasgow to the dealing with infective Siberian horse-hair, the Depart-

ment is indebted to Dr. Russell, the Health Officer of that city, Appendix No. 7. Dangers of this sort are, as may be readily understood, apt to be limited, in the first instance at all events, pretty strictly to the persons of actual workers in the offensive material, but circumstances of conveyance, delivery, and storage may cause them to be operative beyond the immediate area of the trade premises.—In a second sort of trade processes, again, inorganic vapours and gases acknowledgedly poisonous, were given off in quantity, in a way to produce their special poisonous phenomena; and this sort of influence was found to be manifested in a notable degree outside the works at which the effluvia were given off. This was the case with arsenical vapours given off from galvanizing works: with metallic fumes from the melting up of old brass; and (again to take a case where the offence was not from the actually poisonous substance but from something associated with it) with carbonic oxide gas from lime-kilns.

Leaving these two sorts of offensive business, where there is some major evil influence apart from simple offence, the bulk of Dr. Ballard's report is concerned with trades and trade processes in which offence of one kind or another is the prominent feature. In these he recognises several sorts of influence upon health :—

(1.) There is first the influence of stink as stink; an influence found to be common to offensive businesses as such, and independent of the nature of the material or process causing the offence. This influence consists in a group of symptoms of singular constancy representing a disturbance of digestive and circulating functions along with and probably due to a number of sensory disturbances—loss of appetite, nausea, sometimes actual vomiting, sometimes diarrhœa, headache, giddiness, faintness, and a general sense of depression or malaise. It is an influence from which some individuals suffer more than others, and to which some persons become more sensitive, while others become less sensitive, with custom and time; an influence from which people, who from any other cause are sickly, are particularly liable to suffer, and even to suffer to a serious degree.

(2.) Then, there is another influence of certain trade effluvia of various kinds and of various degrees of offensiveness, that consists in their exerting an acrid irritating effect on the surfaces of the body. The vapours of acids and the products of destructive distillation of oils and fats are types of these effluvia. To workers in factories where they are produced they are a source of serious distress or discomfort to eyes, throat, and air-tubes, and even to the skin; while to dwellers in the neighbourhood, they occasion in a less degree irritation to any exposed mucous membrane.

(3.) It is after arriving at this point by a succession of cautious steps, that Dr. Ballard would proceed to consider the effect of offensive trades in producing definite disease and in actually shortening life; and it is here that he begins to regret

his inability to apply the usual methods of differential inquiry, by means of statistics of disease and death, into the influence of one and another disease-producing condition. Of effect upon comfort and ease of life he has sufficient assurance in the case of a variety of trade processes; but when he passes on to consider the evidence respecting further and more serious effects upon health and life, whether among workers or neighbours, he finds himself in want of the usual means of demonstrating relation between observed disease and the offensive trade as the cause of it. Trade influences proper are found not to be capable of differentiation from influences incidental to place of work, or even from others independent of trade altogether. Given, for example, continued respiration in the neighbourhood of offensive works of an atmosphere moderately charged with sulphuretted hydrogen, and an observed depression of general health with some nervous disturbance in persons exposed; other circumstances such as conditions of lodgment and diet, would have to be taken into account before the offensive gas and the failing health could be connected as cause and effect: and it was not possible so to extend the inquiry, even if needful data had existed, as to take account of these things. Yet suggestions of the reality of such connexion were in this instance not lacking, even in such limited investigation as was practicable. Of like nature was an appearance of injury to health from the offensive effluvia from the tank waste of alkali works, especially where waste acid was permitted to mix with the drainage from the waste. So the organs of respiration appeared to suffer (as mentioned in the preceeding section) where acid vapours were largely diffused in the atmosphere, but it was by no means clear that any definite form of disease was produced by those vapours acting by themselves only. About the mischief that was done by them to people already subject to chest complaints there was no doubt, and one of the most common observations in the neighbourhood of those many works from which acid vapours are given off was the aggravation of suffering experienced by people with delicate chests. Of the popular belief that acid gases have conversely some power for good in preventing infectious disease from spreading within the range of their influence, Dr. Ballard finds no evidence whatever.—The report teaches, indeed, that the presence of an offensive business, though it may not rank in the infective or poisonous class, yet deserves to be rated along with and prominent among those conditions that cause one place to be less wholesome than another place. At present it may not be possible to affirm the extent or nature of the share which the business has in the production of the total result, but further progress towards this knowledge may be expected from among the various sanitary observers whom Dr. Ballard has interested in his inquiry.

As regards the second object which the Board has sought to obtain from this inquiry, viz., to learn in what measure and by what means nuisance and injury to health from offensive businesses may be avoided, the report leads to a quite satisfactory result.

It shows that by the application of such knowledge as is now at command, all or nearly all businesses that are now in a serious degree offensive, may be carried on either without offence, or with such important reduction of offence as shall make it tolerable or even trivial. The means of avoiding or lessening offence are fully discussed by Dr. Ballard for the several businesses to which his inquiry has extended, and it is not the least satisfactory feature of his inquiry that "it is commonly found in practice to be as much to the interest of the manufacturers as of the public that the emanations from offensive processes should be thus arrested."

Foreign Epidemics.

V. As regards foreign epidemics, about which the Medical Department has had information; I have first to mention *Plague.* At the time of the last report (July 31, 1878) plague had apparently completely ceased, since the middle of 1877, in Mesopotamia, and there was no certain knowledge of its existence in the localities where it had previously prevailed in Persia and in the Levant. Since that time, so far as information has reached this Department, the disease has remained dormant in the several countries named, but it has manifested itself within the boundaries of Russia in Europe, and at the date of the present report, it exists in the Assyr district of Western Arabia.

In October 1878 plague appeared on the Lower Volga, in the district lying between Tsaritzin and Astrakhan, and there prevailed on both banks of the river, within a limited locality, until February or March of the following year. The materials for a history of this outbreak have not yet been fully completed, and a detailed account of it must be reserved until a future report.

In the last report reference was made to an outbreak of *Cholera* which occurred in Mecca in December 1877. The disease appeared there on the 23rd of that month almost immediately after the termination of the rites of the pilgrimage for the year and when many of the pilgrims had already left the city on their way homewards. The outbreak had been preceded by broken weather, the rain falling in torrents and the temperature being much reduced. When it declared itself the disease was not limited to the pilgrims remaining in and about the city, but it affected also those who formed the caravans which had departed in various directions. The Syrian and Bagdad caravans both suffered, and in their train the disease was carried to Medina, but does not appear to have extended to inhabitants of that city who had not taken part in the pilgrimage. It travelled also with the pilgrims to Jeddah to Confudah and to Hodeidah; and a few cases showed themselves among the pilgrims proceeding northwards by the sea-route, while detained in quarantine at Tor, in the Gulf of Suez. At Mecca from the 23rd December 1877 to the 11th January 1878 the number of deaths recorded from cholera was 785; at Jeddah, from the 25th December 1877 to the 8th January 1878, the number was 186. The total number of

pilgrims present at this year's pilgrimage was estimated at 100,000.

Previous to this outbreak of cholera at Mecca, a French troop-ship, the "Correze," bound from Saigon, Cochin China, to Toulon, had entered the Red Sea and arrived off Suez with convalescents from cholera on board. She had sailed from Saigon on the 19th July 1877, carrying 770 troops, and the day after leaving port cholera appeared among them. From the 20th July to the 16th August, the date of the last case, 60 persons were attacked of whom 32 died. The outbreak had ceased before the vessel touched at Aden, and the last patient from the disease had left hospital when the ship reached Suez on the 24th August. She was sent into quarantine at Tor, and landed there 130 sick affected with "ordinary maladies."

In May 1878 the transports engaged in conveying the British Indian Contingent force from Bombay to Malta passed through the Suez Canal. Two of these ships had had cholera (stray-cases only) on board in the course of the voyage, but one of the affected ships had been 20 days and the other 12 days free from the disease before reaching Suez. The passage of these ships into the Mediterranean, one in free pratique, and the other going through the Maritime Canal in quarantine, gave rise to some uneasiness among the Powers on the littoral, and presently a report became prevalent in the Levant, and was made a subject of official communication, that cholera had broken out among the forces of the Contingent in Malta. There was no actual foundation for this report, as the Contingent remained free from the disease during its stay in Malta and afterwards in Cyprus. No cholera, moreover, appeared among the garrison and population of Malta.

In August 1878, the presence of cholera in Morocco at Fez and Mequinez was officially reported, and subsequently information of the extension of the disease to several of the towns on the Atlantic coast was received. So long as the disease had remained in the interior there would appear to have been difficulties in the way of obtaining confirmatory or other evidence of its nature; but when the malady appeared in the coast towns it became possible to subject it to stricter observation than had previously been practicable. A careful investigation of the supposed cholera was then made by the Medical Officers attached to the Boards of Health of Tangier, Mazagan, and Mogador, and they affirmed, as the result of their observations, that it was not true cholera, but a diarrhœal affection of which the fatality was limited to infants, young children, and old persons, and was caused by the consumption of improper and innutritious food by a starving population—particularly, it would appear from other sources, food prepared from a flour obtained from the root of the *Arum*, and which is apt, it is stated, to become poisonous if certain precautions are not taken in the preparation. At the time of the outbreak the population of the districts in which

this fatal disease had shown itself were suffering from an extremity of famine.

In the course of the year *Yellow fever* became so largely developed in certain ports of the United States of America that in September you thought well to draw the attention of Port Sanitary Authorities in England and Wales to the possibility of the importation of cases of the disease into this country. The intention of the circular which you caused to be issued to these authorities was to allay needless alarm about the extension of the disease if it should chance to be introduced, and to press on Port authorities the importance of having in readiness means of isolation and disinfection for use alike against any exceptional foreign infection, and against those common infectious diseases that travel by ships from one port of this country to another.

VI. It has been customary to re-produce in the annual reports of the Medical Officer the departmental memoranda issued during the year, and I therefore print in Appendix 8 a memorandum based on one previously issued in 1866, "On the Proceedings which are advisable in places attacked or threatened by Epidemic Disease."

VII. During the year satisfactory progress was made in respect of the auxiliary scientific investigations, for which a special annual grant is made by Parliament to the Board. In addition to the inquiry already spoken of as designed to settle the disputed scientific question as to the identity of cow-pox with human small-pox, Dr. Klein was engaged during the year in a continuation of the investigation carried on during 1871 and 1872 into the anatomy of the lymphatic system of the serous membranes and of the lung, with special reference to the process of chronic infective inflammation and tuberculosis. His later inquiries have extended to the lymphatic system of the skin and mucous membranes.

Further, Dr. Thudichum was engaged in continuing his investigations into the chemistry of the brain and into other cognate subjects.

The reports on these investigations, together with the report on the inquiry made for the Board by the Pathological Society into the nature, causes, and prevention of the infective diseases known as Pyæmia, Septicæmia, and Purulent Infection, will appear in the report of the Department for 1879.

I have the honour to be,
Sir,
Your obedient servant,
GEORGE BUCHANAN,
Assistant Medical Officer.

December 24th, 1879.

APPENDIX.

No. 1.

APP. No. 1.

Digest of Vaccination Returns.

DIGEST of the VACCINATION OFFICERS' RETURNS, with regard to CHILDREN whose BIRTHS were registered in the Year 1876.

The following return, which is the fifth annual return under the Vaccination Act, 1871, shows the continued successful working of that Act. Of 887,694* births returned to the Board by the several Vaccination Officers in England and Wales as registered during the year 1876, the number which, at the time the return was made, had been registered as successfully vaccinated was 763,277 (being 86 per cent. of the whole), and the number registered as having died before they could be vaccinated was 84,930 (or 9·5 per cent. of the whole). Of the remaining 39,487 children 848 (or 0·09 per cent. of the whole) had been registered as insusceptible of vaccination†; 107, or (0·01 per cent.) as having contracted small-pox before they could be vaccinated; 5,528 (or 0·62 per cent.) as having their vaccination postponed by medical certificate, leaving 33,004 (or 3·7 per cent.) as "removed," "not to be traced," or otherwise unaccounted for. If from the 887,694 births returned by these officers deduction of the deaths without vaccination be first made, it appears that of the surviving 802,764 children, there were registered at the time of the return 95·08 per cent. as successfully vaccinated; 0·12 per cent. as either insusceptible of vaccination, or as having had small-pox; and 0·69 per cent. as under medical certificate of postponement; leaving 4·11 per cent. as at that time still unaccounted for as regards vaccination.

Of the 33,004 cases which this last per-centage represents, the very large majority were children who could not be found by the Vaccination Officers, usually because of the removal of the parents from the place of birth. In many districts the amount of removals without vaccination was unduly large, on account of delay on the part of the Vaccination Officer in instituting the inquiries which the Board's "Instructions to Vaccination Officers" direct. The remaining cases in the last column (with the exception of a certain number in which vaccination had really been performed successfully, but which could not be registered as vaccinated on account of the legal certificate of vaccination not having been received by the Vaccination Officer) were cases which at the time of the return were still unvaccinated in the union or district of birth. Local imperfections in administrative machinery were the main causes of this default, where it occurred. The number of cases in which non-vaccination was due to direct refusal on the part of parents to comply with the law when required to do so, constitutes as usual only a very small proportion of the cases entered in this column.

Although the results are still less complete in the metropolis than in the rest of the kingdom, it is satisfactory to find from the returns that a marked improvement has taken place in this respect, as the per-centage

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* This number does not include 113 births registered in the Presteigne Union.

† It is probable that of these scarcely any were really insusceptible. The cases included under this heading are children, who being certified as having been three times unsuccessfully vaccinated, are no longer subject to the compulsory provisions of the law.

of cases unaccounted for in the metropolis has fallen from 9·3 per cent. in 1875 to 6·5 per cent. in 1876. The per-centage in the rest of the kingdom has increased by a small fraction, having risen from 3·8 in 1875 to 4·0 in 1876. Of the registered births of the five years 1872–6 the proportion not finally accounted for in regard to vaccination in each year respectively has been in the metropolis 8·8, 8·7, 8·8, 9·3, and 6·5 per cent., while in the rest of the kingdom it has been only 4·5, 4·2, 4·1, 3·8, and 4·0 per cent. In 1876 the proportion of cases unaccounted for, after deduction of the postponed cases, in the metropolis and in the rest of the kingdom, was 5·7 and 3·4 per cent. of births respectively.

RETURNS, 1876.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.	Percentage of Children not finally accounted for, including Cases postponed.
ENGLAND AND WALES.	887,694	763,277	848	107	84,930	5,528	33,004	4·3
Do. excluding Metropolitan Unions.	760,242	656,164	585	60	73,209	4,499	25,725	4·0
METROPOLITAN UNIONS.	127,452	107,113	263	47	11,721	1,029	7,279	6·5
COUNTIES.								
Bedford - -	5,203	4,471	6	1	603	35	87	2·3
Berks - -	7,562	6,667	8	—	610	83	194	3·6
Bucks - -	5,239	4,655	2	—	484	39	59	1·9
Cambridge -	6,265	5,515	1	—	605	33	111	2·3
Chester -	20,381	17,977	22	6	1,887	71	418	2·4
Cornwall -	10,017	8,694	6	—	1,029	76	212	2·8
Cumberland -	8,325	7,270	7	—	815	50	183	2·8
Derby -	14,244	12,166	18	2	1,594	66	398	3·2
Devon - -	17,994	16,027	13	—	1,440	135	379	2·8
Dorset - -	5,492	4,927	3	—	393	43	126	3·0
Durham - -	36,496	30,639	29	—	3,817	159	1,852	5·5
Essex - -	16,675	14,935	9	2	1,373	91	265	2·1
Gloucester - -	17,020	1,4732	17	—	1,588	86	597	4·0
Hereford - -	3,432	2,918	5	—	317	21	171	5·6
Herts - -	7,266	6,580	2	—	566	26	92	1·6
Hunts - -	1,787	1,596	—	—	162	6	23	1·6
Kent (extra-metropolitan).	22,184	19,843	23	4	1,791	154	369	2·3
Lancaster - -	127,684	110,868	79	37	12,543	504	3,653	3·2
Leicester - -	11,753	9,612	11	1	1,457	50	622	5·7
Lincoln - -	14,977	12,373	5	—	1,554	167	878	6·9
Middlesex (extra-metropolitan).	9,532	8,055	11	—	816	32	618	6·8
Monmouth - -	9,040	8,109	2	—	729	40	160	2·2
Norfolk - -	13,384	11,602	9	—	1,418	92	263	2·6
Northampton -	9,297	8,018	5	1	970	69	234	3·2
Northumberland -	16,656	14,464	18	—	1,701	127	346	2·8
Nottingham -	15,522	13,122	13	—	1,730	36	621	4·2
Oxford - -	5,800	4,898	1	—	561	71	269	5·8
Rutland - -	714	615	—	—	70	1	28	4·0
Shropshire - -	8,675	7,644	14	—	801	52	164	2·4
Somerset - -	15,369	13,539	19	1	1,304	124	382	3·3
Southampton -	17,218	15,302	26	1	1,307	168	414	3·3
Stafford - -	34,090	29,395	25	—	3,465	128	1,077	3·5
Suffolk - -	11,248	9,898	10	1	964	79	296	3·3
Surrey (extra metropolitan).	13,097	11,555	15	1	1,005	102	419	3·9
Sussex - -	13,660	11,997	14	—	1,110	141	398	3·9
Warwick - -	25,688	21,809	28	—	2,491	75	1,285	5·3
Westmoreland -	2,046	1,828	6	—	168	11	33	2·1
Wilts - -	7,703	6,985	5	—	553	60	100	2·1
Worcester - -	20,090	17,298	18	—	2,033	137	604	3·6
York, E. R. - -	12,204	10,445	21	—	1,264	62	412	3·9
York, N. R. - -	12,440	10,793	12	—	1,153	143	339	3·8
York, W. R. - -	80,081	65,568	36	2	8,662	383	5,430	7·2
WALES.								
Anglesey - -	993	842	1	—	113	5	32	3·7
Brecknock - -	1,909	1,678	1	—	185	6	39	2·3
Cardigan - -	2,192	1,960	—	—	165	27	40	3·0
Carmarthen - -	4,360	3,992	1	—	317	14	36	1·1
Carnarvon - -	3,502	3,083	1	—	351	34	33	1·9
Denbigh - -	2,971	2,522	1	—	307	42	99	4·7
Flint - - -	2,929	2,623	1	—	232	22	51	2·5
Glamorgan - -	20,100	17,426	4	—	1,879	184	607	3·9
Merioneth - -	2,081	1,769	—	—	239	34	39	3·5
Montgomery -	2,460	2,117	1	—	239	34	69	4·2
Pembroke - -	2,670	2,304	—	—	233	68	65	4·9
Radnor - -	525	444	—	—	46	1	34	6·6

UNIONS.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.	Percentage of children not finally accounted for, including Cases postponed.
METROPOLITAN UNIONS.								
Bethnal Green - -	5,307	4,471	3	2	540	30	261	5·4
Camberwell - -	5,286	4,361	15	1	504	32	373	7·6
Chelsea - - -	2,568	2,082	15	—	325	3	143	5·7
Fulham - - -	3,322	2,774	9	1	338	20	180	6·0
George, St., Hanover Square	4,138	3,449	20	2	350	22	295	7·6
George St., in the East -	1,811	1,400	—	—	210	6	195	11·1
Giles St. and George St. -	1,671	1,345	—	—	171	2	153	9·2
Greenwich - -	4,191	3,561	5	1	330	164	130	7·0
Hackney - - -	5,522	4,662	16	6	485	48	305	6·3
Hampstead - -	952	826	3	—	60	9	54	6·6
Holborn - - -	6,027	5,148	7	—	552	8	312	5·3
Islington - - -	9,226	7,826	9	—	779	157	455	6·6
Kensington - -	4,519	3,889	24	5	409	22	170	4·2
Lambeth - - -	8,931	7,378	36	7	871	11	628	7·1
Lewisham - - -	1,986	1,803	3	—	151	5	24	1·5
London, City - -	1,514	1,280	—	—	138	23	73	6·3
Marylebone - -	5,099	3,932	10	—	600	70	487	10·9
Mile End Old Town -	4,034	3,328	6	5	407	75	213	7·1
Olave, St. - - -	5,423	4,747	13	—	459	33	171	3·7
Paddington - -	2,905	2,463	10	—	242	22	168	6·5
Pancras, St. - -	8,337	7,163	12	—	634	6	522	6·3
Poplar - - -	5,893	5,197	10	8	497	7	174	3·1
Saviour, St. - -	7,398	6,224	3	1	698	60	412	6·4
Shoreditch - -	5,237	4,114	4	1	482	108	528	11·9
Stepney - - -	2,202	1,795	2	2	270	9	124	6·0
Strand - - -	1,013	787	2	—	122	—	102	10·0
Wandsworth and Clapham	6,022	5,219	19	3	538	24	219	4·0
Westminster - -	1,397	1,207	4	1	128	9	48	4·1
Whitechapel - -	2,764	2,241	1	—	244	29	249	10·0
Woolwich - -	2,757	2,441	2	1	187	15	111	4·0
BEDFORDSHIRE.								
Ampthill - - -	634	549	1	—	79	—	5	
Bedford - - -	1,345	1,207	—	—	128	4	6	
Biggleswade - -	904	762	1	—	120	7	14	
Leighton Buzzard -	673	590	2	—	66	3	12	
Luton - - -	1,326	1,078	2	1	177	20	48	
Woburn - - -	321	285	—	—	33	1	2	
BERKS.								
Abingdon - - -	721	659	1	—	53	3	5	
Bradfield - - -	448	413	—	—	32	1	2	
Cookham - - -	468	402	1	—	37	9	19	
Easthampstead - -	319	284	1	—	27	2	5	
Faringdon - -	458	417	1	—	33	1	6	
Hungerford - -	536	494	—	—	38	1	3	
Newbury - - -	625	534	1	—	53	23	14	
Reading - - -	1,422	1,261	—	—	122	17	22	
Wallingford - -	466	416	1	—	39	2	8	
Wantage - - -	558	503	1	—	47	3	4	
Windsor - - -	923	752	1	—	88	7	75	
Wokingham - -	618	532	—	—	41	14	31	

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
BUCKS.							
Amersham - -	652	594	—	—	53	—	5
Aylesbury - - -	821	710	—	—	86	12	13
Buckingham - -	394	344	—	—	40	4	6
Eton - - -	777	699	1	—	67	4	6
Newport Pagnell - -	837	759	1	—	60	7	10
Winslow - - -	268	235	—	—	24	3	6
Wycombe - - -	1,490	1,314	—	—	154	9	13
CAMBRIDGE.							
Cambridge - -	987	859	1	—	106	7	14
Caxton and Arrington -	418	387	—	—	29	—	2
Chesterton - -	971	845	—	—	92	8	26
Ely - - -	721	617	—	—	80	1	23
Linton - - -	429	382	—	—	23	6	18
Newmarket - -	902	822	—	—	71	3	6
North Witchford - -	512	456	—	—	46	—	10
Whittlesey - -	221	195	—	—	20	4	2
Wisbeach - - -	1,104	952	—	—	138	4	10
CHESHIRE.							
Altrincham - -	1,717	1,551	5	—	142	2	17
Birkenhead - -	3,565	3,164	3	3	298	6	91
Tarvin - - -	333	297	—	—	27	2	7
Chester - - -	1,546	1,409	1	—	133	1	2
Congleton - - -	1,403	1,236	1	—	144	8	14
Macclesfield - -	2,063	1,812	2	—	193	18	38
Nantwich - - -	2,091	1,755	5	2	197	18	114
Northwich - -	1,616	1,460	—	—	140	—	16
Runcorn - - -	1,303	1,164	—	1	119	2	17
Stockport - - -	4,028	3,479	3	—	452	9	85
Wirrall - - -	716	650	2	—	42	5	17
CORNWALL.							
Austell, St. - -	1,003	893	1	—	95	7	7
Bodmin - - -	558	483	—	—	46	3	26
Camelford - -	262	245	—	—	16	—	1
Columb, St., Major -	544	495	—	—	42	—	7
Falmouth - - -	710	604	1	—	83	5	17
Germans, St. - -	477	431	1	—	31	3	11
Helston - - -	772	614	—	—	128	6	24
Launceston - -	499	448	—	—	45	5	1
Liskeard - - -	912	811	—	—	79	12	10
Penzance - - -	1,526	1,307	1	—	177	8	33
Redruth - - -	1,458	1,248	1	—	152	10	47
Stratton - - -	221	194	—	—	18	4	5
Truro - -	1,075	921	1	—	117	13	23
CUMBERLAND.							
Alston with Garrigill -	140	121	—	—	16	1	2
Bootle - - -	403	359	—	—	32	2	10
Brampton - - -	304	281	—	—	20	—	3
Carlisle - - -	1,662	1,457	—	—	183	3	19
Cockermouth - -	1,904	1,653	1	—	200	7	43
Longtown - - -	250	221	—	—	23	5	1
Penrith - - -	654	591	1	—	59	—	3
Whitehaven - -	2,339	1,999	3	—	216	26	95
Wigton - -	669	588	2	—	66	6	7

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Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
DERBY.							
Ashbourne - -	639	538	2	—	80	3	16
Bakewell - - -	916	789	1	—	102	5	19
Belper - - -	2,234	2,000	2	—	206	—	26
Chapel-en-le-Frith -	602	512	—	—	64	7	19
Chesterfield - -	4,364	3,750	7	—	454	28	125
Derby - - -	2,844	2,348	—	—	414	—	82
Glossop - - -	734	605	1	2	100	1	25
Hayfield - - -	438	377	—	—	40	8	13
Shardlow - - -	1,473	1,247	5	—	134	14	73
DEVON.							
Axminster - -	541	484	—	—	41	—	16
Barnstaple - -	1,062	971	—	—	72	11	8
Bideford - - -	567	521	—	—	39	4	3
Crediton - - -	572	518	1	—	39	6	8
East Stonehouse - -	557	489	—	—	53	6	9
Exeter - - -	1,056	890	1	—	122	12	31
Holsworthy - -	314	280	—	—	26	4	4
Honiton - - -	704	641	—	—	44	9	10
Kingsbridge - -	593	551	—	—	34	1	7
Newton Abbot - -	1,968	1,757	—	—	161	17	33
Okehampton - -	555	496	—	—	46	8	5
Plymouth - - -	2,170	1,857	—	—	208	20	85
Plympton St. Mary -	694	590	—	—	69	12	23
South Molton - -	532	498	—	—	29	2	3
Stoke Damerel - -	1,406	1,239	—	—	105	—	62
Tavistock - - -	870	796	3	—	57	1	13
Thomas, St. - -	1,424	1,282	4	—	102	7	29
Tiverton - - -	834	737	2	—	78	7	10
Torrington - -	463	417	—	—	33	2	11
Totnes - - -	1,112	1,013	2	—	82	6	9
DORSET.							
Beaminster - -	376	334	—	—	35	—	7
Blandford - - -	388	340	1	—	33	6	8
Bridport - - -	464	408	—	—	45	1	10
Cerne - - -	193	175	—	—	15	—	3
Dorchester - -	523	473	1	—	44	1	4
Poole - - -	578	515	1	—	35	9	18
Shaftesbury - -	405	350	—	—	28	6	21
Sherborne - -	375	352	—	—	20	—	3
Sturminster - -	303	279	—	—	23	—	1
Wareham and Purbeck -	528	484	—	—	32	5	7
Weymouth - -	850	741	—	—	63	12	34
Wimborne and Cranborne	509	476	—	—	20	3	10
DURHAM.							
Auckland - - -	3,916	3,314	6	—	432	10	154
Chester-le-Street - -	1,914	1,674	3	—	214	—	23
Darlington - -	1,817	1,577	1	—	142	3	94
Durham - - -	2,999	2,504	7	—	355	29	104
Easington - -	2,014	1,619	—	—	235	5	155
Gateshead - -	4,435	3,515	—	—	498	18	404
Hartlepool - -	1,910	1,687	1	—	194	9	19
Houghton-le-Spring -	1,516	1,325	5	—	164	1	21
Lanchester - -	2,546	2,065	—	—	226	5	250

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
DURHAM—*cont.*							
Sedgefield - -	951	811	—	—	100	5	35
South Shields - -	3,967	3,245	3	—	432	38	249
Stockton - - -	1,960	1,616	1	—	195	13	135
Sunderland - -	5,172	4,485	2	—	485	15	185
Teesdale - - -	706	624	—	—	62	6	14
Weardale - - -	673	578	—	—	83	2	10
ESSEX.							
Billericay - - -	481	418	—	—	36	2	25
Braintree - - -	527	471	—	—	47	2	7
Chelmsford - -	995	894	—	—	83	8	10
Colchester - -	887	775	3	—	89	9	11
Dunmow - - -	574	533	—	—	32	5	4
Epping - - -	673	593	—	—	57	3	20
Halstead - - -	576	520	—	—	40	8	8
Lexden and Winstree -	793	733	—	—	54	1	5
Maldon - -	830	748	—	—	70	4	8
Ongar - - -	342	298	—	—	24	4	16
Orsett - - -	483	434	—	—	36	3	10
Rochford - - -	783	689	—	—	80	—	14
Romford - - -	1,198	1,083	2	—	91	1	21
Saffron Walden - -	557	512	—	—	32	1	12
Tendring - - -	952	849	—	—	83	—	16
West Ham - -	5,569	4,962	4	2	495	31	75
Witham - - -	455	423	—	—	24	5	3
GLOUCESTER.							
Barton Regis - -	5,732	5,005	11	—	520	14	182
Bristol - -	2,043	1,734	2	—	222	14	71
Cheltenham - -	1,298	946	2	—	178	11	161
Chipping Sodbury -	564	495	1	—	52	11	5
Cirencester - -	630	569	—	—	47	1	13
Dursley - - -	419	371	—	—	39	4	5
Gloucester - -	1,533	1,334	—	—	139	10	50
Newent - - -	355	326	1	—	23	—	5
Northleach - -	297	261	—	—	23	2	11
Stow-on-the-Wold -	255	212	—	—	13	5	25
Stroud - - -	1,317	1,184	—	—	119	3	11
Tetbury - - -	168	150	—	—	10	3	5
Tewkesbury - -	424	372	—	—	39	—	13
Thornbury - -	529	484	—	—	41	—	4
Westbury-on-Severn -	959	842	—	—	82	6	29
Wheatenhurst - -	197	187	—	—	10	—	—
Winchcomb - -	300	260	—	—	31	2	7
HEREFORD.							
Bromyard - -	348	303	1	—	29	5	10
Dore - - -	254	233	—	—	20	1	—
Hereford - - -	953	836	2	—	91	4	20
Kington - - -	360	326	—	—	31	1	2
Ledbury - - -	338	302	—	—	20	5	11
Leominster - -	418	360	1	—	41	1	15
Ross - - -	527	347	—	—	69	4	107
Weobley - - -	234	211	1	—	16	—	6

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Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
HERTS.							
Albans, St. - -	725	670	—	—	46	1	8
Barnet - - -	862	777	1	—	62	1	21
Berkhampstead - -	510	437	—	—	59	5	9
Bishop's Stortford -	697	631	1	—	55	2	8
Buntingford - -	209	197	—	—	12	—	—
Hatfield - - -	202	190	—	—	10	1	1
Hemel Hempstead -	509	463	—	—	39	—	7
Hertford - - -	477	446	—	—	26	2	3
Hitchin - - -	948	841	—	—	94	—	13
Royston - - -	622	568	—	—	50	—	4
Ware - - -	545	492	—	—	36	10	7
Watford - - -	873	788	—	—	73	4	8
Welwyn - - -	87	80	—	—	4	—	3
HUNTINGDON.							
Huntingdon - -	652	576	—	—	62	1	13
Ives, St. - - -	546	490	—	—	48	4	4
Neots, St. - - -	589	530	—	—	52	1	6
KENT (extra metropolitan).							
Ashford, East - -	436	392	—	—	37	1	6
Ashford, West - -	594	538	—	—	45	4	7
Blean - - -	626	579	—	—	41	1	5
Bridge - - -	381	343	—	—	30	—	8
Bromley - - -	1,370	1,148	2	—	158	36	26
Canterbury - -	576	509	—	—	48	—	19
Cranbrook - -	435	392	1	—	24	4	14
Dartford - - -	1,620	1,472	6	1	113	7	21
Dover - - -	1,131	968	—	—	100	24	39
Eastry - - -	771	685	—	—	56	16	14
Elham - - -	997	873	1	—	98	11	14
Faversham - -	844	775	—	—	58	4	7
Gravesend and Milton -	718	662	—	—	41	—	15
Hollingbourn - -	454	394	—	—	49	3	8
Hoo - - -	125	116	—	—	8	—	1
Maidstone - -	1,524	1,342	3	—	137	4	38
Malling - - -	894	797	1	—	79	3	14
Medway - - -	2,071	1,861	2	2	184	1	21
Milton - - -	812	746	1	—	62	1	2
North Aylesford - -	902	804	1	1	86	1	9
Romney Marsh - -	201	184	—	—	16	—	1
Sevenoaks - -	844	762	1	—	57	4	20
Sheppey - - -	606	549	2	—	41	4	10
Tenterden - -	361	327	1	—	29	1	3
Thanet, Isle of - -	1,328	1,205	—	—	96	10	17
Tonbridge - -	1,563	1,420	1	—	98	14	30
LANCASHIRE.							
Ashton-under-Lyne -	5,701	5,024	5	—	569	23	80
Barrow-in-Furness -	1,688	1,429	—	—	172	11	76
Barton-upon-Irwell -	2,295	1,969	—	—	194	18	114
Blackburn - -	6,462	5,813	4	—	614	7	24
Bolton - - -	7,380	6,603	3	1	618	—	155
Burnley - - -	4,031	3,525	—	2	437	18	49
Bury - - -	4,502	3,915	2	—	454	14	117

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
LANCASHIRE—*cont.*							
Chorley - - -	1,779	1,537	—	—	182	15	45
Chorlton - - -	9,259	7,868	6	3	961	10	411
Clitheroe - - -	727	641	1	—	71	2	12
Fylde, The - -	1,282	1,117	—	—	114	1	50
Garstang - - -	388	349	—	—	35	—	4
Haslingden - -	3,240	2,877	2	—	277	10	74
Lancaster - -	1,222	1,066	—	—	124	8	24
Leigh - - -	2,228	1,990	—	—	202	1	35
Liverpool - - -	7,871	6,604	8	2	894	8	355
Lunesdale - -	203	181	—	—	19	1	2
Manchester - -	6,783	5,663	5	1	778	54	282
Oidham - - -	5,883	4,974	7	—	619	64	219
Ormskirk - - -	2,495	2,179	3	—	223	12	78
Prescot - - -	4,631	4,005	—	—	465	31	130
Preston - - -	4,684	4,013	—	1	540	14	116
Prestwich - -	3,852	3,372	4	2	316	17	141
Rochdale - - -	4,199	3,637	1	1	413	21	126
Salford - - -	7,025	5,974	10	7	740	39	255
Todmorden - -	1,159	1,001	—	—	126	8	24
Toxteth Park - -	4,037	3,435	2	3	368	8	221
Ulverstone - -	1,585	1,404	1	—	138	10	32
Warrington - -	2,704	2,400	—	—	232	21	51
West Derby - -	12,217	10,833	15	14	1,046	49	260
Wigan - - -	6,172	5,470	—	—	602	9	91
LEICESTER.							
Ashby-de-la-Zouch -	1,344	1,131	—	—	133	5	75
Barrow-on-Soar - -	995	802	—	—	137	5	51
Billesdon - - -	260	208	—	—	36	1	15
Blaby - - -	673	582	2	—	68	3	18
Hinckley - -	693	611	—	—	77	—	5
Leicester - - -	4,773	3,650	9	1	679	27	407
Loughborough - -	950	814	—	—	120	6	10
Lutterworth - -	348	303	—	—	40	1	4
Market Bosworth -	558	493	—	—	55	1	9
Market Harborough -	496	426	—	—	58	—	12
Melton Mowbray - -	663	592	—	—	54	1	16
LINCOLNSHIRE.							
Boston - - -	1,190	981	—	—	125	7	77
Bourn - - -	633	544	—	—	58	18	13
Caistor - - -	2,171	1,614	2	—	274	48	233
Gainsborough - -	926	704	—	—	111	8	103
Glanford Brigg - -	1,388	1,189	—	—	144	11	44
Grantham - -	1,132	1,000	1	—	112	5	14
Holbeach - - -	713	628	—	—	56	6	23
Horncastle - -	711	634	—	—	61	2	14
Lincoln - - -	2,072	1,545	2	—	263	29	233
Louth - - -	1,019	874	—	—	89	22	34
Sleaford - - -	838	769	—	—	57	—	12
Spalding - - -	758	669	—	—	75	1	13
Spilsby - - -	858	718	—	—	80	7	53
Stamford - - -	568	504	—	—	49	3	12

App. No. 1.

Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
MIDDLESEX (extra metropolitan).							
Brentford - - -	2,719	2,066	—	—	263	7	383
Edmonton - -	3,666	3,244	6	—	293	13	110
Hendon - - -	1,581	1,352	5	—	140	5	79
Staines - - -	762	676	—	—	49	7	30
Uxbridge - - -	804	717	—	—	71	—	16
MONMOUTHSHIRE.							
Abergavenny - -	849	763	—	—	79	—	7
Bedwellty - - -	2,403	2,162	—	—	185	—	56
Chepstow - - -	584	515	—	—	53	2	14
Monmouth - -	1,118	1,033	—	—	64	5	16
Newport - - -	2,644	2,355	2	—	230	14	43
Pontypool - -	1,442	1,281	—	—	118	19	24
NORFOLK.							
Aylsham - - -	527	460	—	—	54	1	12
Blofield - - -	319	271	—	—	42	3	3
Depwade - -	705	611	4	—	58	10	22
Docking - - -	525	471	—	—	47	3	4
Downham - -	652	568	—	—	68	5	11
Erpingham - -	612	545	—	—	55	3	9
Faith, St. - - -	363	321	—	—	38	1	3
Flegg, East and West -	298	255	—	—	32	1	10
Forehoe - - -	345	302	—	—	26	4	13
Freebridge Lynn - -	408	355	—	—	39	8	6
Guiltcross - -	308	248	—	—	45	—	15
Henstead - -	307	272	2	—	26	3	4
King's Lynn - -	516	443	—	—	59	1	13
Loddon and Clavering -	404	351	1	—	41	2	9
Mitford and Launditch -	838	758	—	—	68	5	7
Norwich - - -	2,809	2,435	1	—	324	5	44
Swaffham - - -	389	340	—	—	36	5	8
Thetford - - -	521	440	—	—	66	4	11
Smallburgh - -	446	386	—	—	44	3	13
Walsingham - -	592	510	—	—	60	6	16
Wayland - - -	296	258	—	—	34	3	1
Yarmouth, Great - -	1,204	1,002	1	—	156	16	29
NORTHAMPTONSHIRE.							
Brackley - - -	392	331	—	—	45	6	10
Brixworth - -	375	346	—	—	25	1	3
Daventry - - -	552	482	—	—	58	3	9
Hardingstone - -	368	330	—	—	34	3	1
Kettering - - -	862	771	1	—	72	1	17
Northampton - -	2,199	1,792	2	1	287	10	107
Oundle - - -	420	378	1	—	34	—	7
Peterborough - -	1,472	1,304	—	—	149	3	16
Potterspury - -	380	321	—	—	36	5	18
Thrapston - - -	546	485	-	—	55	—	6
Towcester - -	444	404	—	—	33	4	3
Wellingborough - -	1,287	1,074	1	—	142	33	37

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
NORTHUMBERLAND.							
Alnwick - - -	677	622	—	—	42	3	10
Belford - - -	165	157	—	—	8	—	—
Bellingham - -	204	179	—	—	18	1	6
Berwick-on-Tweed -	658	588	—	—	55	8	7
Castle Ward - -	722	641	—	—	75	—	6
Glendale - - -	292	268	—	—	19	—	5
Haltwhistle - -	276	254	—	—	19	2	1
Hexham - - -	1,133	998	2	—	95	8	30
Morpeth - - -	1,748	1,542	—	—	172	7	27
Newcastle-on-Tyne -	5,988	5,085	10	—	684	51	158
Rothbury - - -	189	177	—	—	11	1	—
Tynemouth - -	4,604	3,953	6	—	503	46	96
NOTTINGHAMSHIRE.							
Basford - - -	4,790	4,098	6	—	532	8	146
Bingham - - -	479	412	—	—	49	5	13
East Retford - -	744	663	—	—	60	—	21
Mansfield - - -	1,856	1,572	—	—	235	6	43
Newark - - -	997	886	3	—	97	—	11
Nottingham - -	3,474	2,766	2	—	415	3	288
Radford - - -	1,491	1,216	2	—	202	2	69
Southwell - -	585	529	—	—	45	—	11
Worksop - - -	1,106	980	—	—	95	12	19
OXFORDSHIRE.							
Banbury - - -	1,015	692	—	—	127	27	169
Bicester - - -	459	392	—	—	50	6	11
Chipping Norton - -	601	499	—	—	79	10	13
Headington - -	795	687	—	—	73	5	30
Henley - - -	610	558	—	—	46	4	2
Oxford - - -	675	586	—	—	63	6	20
Thame - - -	482	433	—	—	39	4	6
Witney - - -	729	667	—	—	53	3	6
Woodstock - -	434	384	1	—	31	6	12
RUTLAND.							
Oakham - - -	326	285	—	—	31	—	10
Uppingham - -	388	330	—	—	39	1	18
SALOP.							
Atcham - - -	1,353	1,211	—	—	107	12	23
Bridgnorth - -	425	364	—	—	39	3	19
Church Stretton - -	166	151	1	—	10	—	4
Cleobury Mortimer -	285	254	—	—	25	1	5
Clun - - -	326	285	—	—	27	2	12
Drayton - - -	462	417	—	—	38	—	7
Ellesmere - - -	396	350	—	—	40	3	3
Ludlow - - -	570	478	7	—	58	6	21
Madeley - - -	1,130	968	3	—	128	12	19
Newport - - -	501	445	—	—	45	2	9
Oswestry - - -	904	816	1	—	75	2	10
Shifnal - - -	422	376	—	—	33	1	12
Wellington - -	1,081	950	2	—	117	1	11
Wem - - -	308	283	—	—	20	2	3
Whitchurch - -	346	296	—	—	39	5	6

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Digest of Vaccination Returns.

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
SOMERSET.							
Axbridge - - -	1,095	971	3	—	93	10	18
Bath - - -	1,958	1,598	3	—	210	5	142
Bedminster - -	2,405	2,063	2	—	260	37	43
Bridgwater - -	1,090	966	3	—	81	11	29
Chard - - -	849	739	—	—	84	10	16
Clutton - - -	841	790	—	—	45	—	6
Dulverton -	180	163	—	—	14	1	2
Frome - - -	751	681	—	—	56	4	10
Keynsham - -	913	814	—	—	85	5	9
Langport - - -	503	437	—	—	24	—	42
Shepton Mallet - -	471	431	—	—	36	1	3
Taunton - - -	978	888	2	—	63	10	15
Wellington - -	547	501	2	—	35	—	9
Wells - - -	676	601	2	1	57	7	8
Williton - - -	584	531	1	—	40	7	5
Wincanton - -	609	552	—	—	40	5	12
Yeovil - -	919	813	1	—	81	11	13
SOUTHAMPTON.							
Alresford - - -	172	159	3	—	9	—	1
Alton - - -	543	495	—	1	35	2	10
Alverstoke - -	735	683	4	—	44	—	4
Andover - - -	495	445	—	—	41	4	5
Basingstoke - -	591	513	—	—	40	12	26
Catherington - -	82	68	—	—	8	1	5
Christchurch - -	749	626	3	—	84	16	20
Droxford - - -	334	303	—	—	22	1	8
Fareham - - -	486	438	—	—	39	1	8
Fordingbridge - -	203	193	—	—	9	—	1
Hartley Wintney - -	525	464	1	—	41	1	18
Havant - - -	249	221	—	—	15	1	12
Hursley - - -	91	86	—	—	3	—	2
Kingsclere - -	291	271	—	—	14	—	6
Lymington - -	358	320	—	—	25	8	5
New Forest - -	385	352	—	—	25	—	8
Petersfield - -	321	293	—	—	20	—	8
Portsea Island - -	4,066	3,688	5	—	308	16	49
Ringwood - - -	167	157	—	—	7	1	2
Romsey - - -	321	272	—	—	34	3	12
Southampton - -	1,752	1,456	1	—	187	20	88
South Stoneham -	1,109	947	2	—	87	22	51
Stockbridge - -	209	190	—	—	17	1	1
Whitchurch - -	163	143	—	—	10	4	6
Wight, Isle of - -	2,073	1,854	5	—	119	49	46
Winchester, New - -	748	665	2	—	64	5	12
STAFFORDSHIRE.							
Wolstanton and Burslem -	3,284	2,911	—	—	323	1	49
Burton-on-Trent - -	2,660	2,146	2	—	251	33	228
Cannock - - -	1,374	1,173	—	—	158	10	33
Cheadle - - -	850	740	—	—	95	3	12
Leek - - -	1,119	954	—	—	117	7	41
Lichfield - - -	1,400	1,209	4	—	131	12	44
Newcastle-under-Lyme -	1,391	1,089	—	—	178	—	124
Seisdon - - -	507	457	1	—	43	1	5
Stafford - - -	990	862	—	—	84	4	40
Stoke-upon-Trent -	4,451	3,866	—	—	465	13	107

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
STAFFORDSHIRE—*cont.*							
Stone - - -	926	812	1	—	101	1	11
Tamworth - -	729	642	—	—	65	4	18
Uttoxeter - - -	471	430	2	—	36	—	3
Walsall - - -	3,515	2,923	3	—	411	32	146
West Bromwich - -	5,160	4,557	10	—	482	5	106
Wolverhampton - -	5,263	4,624	2	—	525	2	110
SUFFOLK.							
Blything - - -	837	735	1	—	62	9	30
Bosmere and Claydon -	484	413	—	—	51	—	20
Bury St. Edmunds -	536	472	1	—	48	5	10
Cosford - - -	499	444	4	—	38	—	13
Hartismere - -	495	447	—	—	40	2	6
Hoxne - - -	468	411	—	—	41	4	12
Ipswich - - -	1,583	1,373	2	1	154	21	32
Mildenhall - -	262	238	—	—	18	—	6
Mutford and Lothingland -	1,249	1,083	—	—	106	4	56
Plomesgate - -	628	567	—	—	43	4	14
Risbridge - - -	601	539	—	—	57	2	3
Samford - - -	329	287	1	—	31	3	7
Stow - - -	674	576	—	—	75	1	22
Sudbury - - -	956	858	1	—	79	2	16
Thingoe - - -	487	445	—	—	37	1	4
Wangford - - -	432	345	—	—	41	18	28
Woodbridge - -	728	665	—	—	43	3	17
SURREY (extra metropolitan.)							
Chertsey - - -	817	723	—	—	56	12	26
Croydon - - -	3,291	2,772	5	1	302	29	182
Dorking - - -	455	419	—	—	27	—	9
Epsom - - -	1,077	947	—	—	81	8	41
Farnham - - -	1,570	1,367	—	—	142	4	57
Godstone - - -	422	393	—	—	21	—	8
Guildford - - -	1,108	1,023	2	—	62	10	11
Hambledon - -	492	464	—	—	21	1	6
Kingston - - -	2,111	1,867	3	—	161	31	49
Reigate - - -	879	776	4	—	70	7	22
Richmond - -	875	804	1	—	62	—	8
SUSSEX.							
Battle - -	469	430	—	—	22	4	6
Brighton - - -	2,809	2,502	3	—	260	10	34
Chailey - - -	284	251	—	—	22	—	11
Chichester - -	255	216	—	—	18	10	11
Cuckfield - - -	602	528	—	—	45	11	18
Eastbourne - -	623	540	—	—	54	11	18
East Grinstead - -	566	510	—	—	39	3	14
East Preston - -	660	598	1	—	40	2	19
Hailsham - - -	454	407	—	—	27	3	17
Hastings - - -	1,234	992	2	—	112	43	85
Horsham - - -	607	538	1	—	43	3	22
Lewes - - -	322	273	—	—	24	9	16

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
SUSSEX—*cont.*							
Midhurst	406	376	—	—	24	1	5
Newhaven	225	183	3	—	23	—	16
Petworth	264	241	—	—	17	1	5
Rye	365	333	2	—	24	1	5
Steyning	1,142	962	1	—	131	12	36
Thakeham	271	245	1	—	20	—	5
Ticehurst	570	492	—	—	45	9	24
Uckfield	659	599	—	—	48	2	10
Westbourne	239	219	—	—	12	—	8
West Firle	75	62	—	—	10	1	2
West Hampnett	559	500	—	—	43	5	11
WARWICKSHIRE.							
Alcester	608	533	1	—	55	6	13
Aston	7,989	6,880	4	—	730	18	357
Atherstone	503	452	—	—	40	2	9
Birmingham	9,923	8,117	18	—	1,021	20	747
Coventry	1,552	1,336	1	—	182	9	24
Foleshill	724	622	—	—	81	—	21
Meriden	304	281	—	—	20	—	3
Nuneaton	483	411	—	—	51	6	15
Rugby	800	718	—	—	66	5	11
Solihull	470	420	—	—	31	1	18
Southam	316	276	—	—	30	2	8
Stratford-on-Avon	721	638	—	—	52	3	28
Warwick	1,295	1,125	4	—	132	3	31
WESTMORELAND.							
East Ward	453	385	—	—	44	2	22
Kendal	1,348	1,217	6	—	106	9	10
West Ward	245	226	—	—	18	—	1
WILTSHIRE.							
Alderbury	760	699	—	—	52	2	7
Amesbury	222	204	—	—	14	—	4
Bradford	354	326	—	—	27	—	1
Calne	255	240	1	—	12	2	—
Chippenham	665	596	1	—	49	10	9
Cricklade and Wootton Bassett.	355	309	—	—	25	11	10
Devizes	627	570	1	—	38	7	11
Highworth and Swindon	1,234	1,106	—	—	104	5	19
Malmesbury	458	415	—	—	34	7	2
Marlborough	266	257	—	—	8	—	1
Melksham	604	523	—	—	63	3	15
Mere	210	192	—	—	17	1	—
Pewsey	338	311	—	—	24	—	3
Tisbury	278	247	1	—	19	2	9
Warminster	390	363	—	—	17	5	5
Westbury and Whorwelsdown.	356	328	—	—	25	2	1
Wilton	331	299	1	—	25	3	3

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
WORCESTERSHIRE.							
Bromsgrove - -	1,102	998	—	—	93	2	9
Droitwich - - -	811	710	—	—	80	4	17
Dudley - - -	6,785	5,745	13	—	774	39	214
Evesham - - -	478	427	1	—	41	2	7
Kidderminster - -	1,329	1,203	—	—	103	1	22
King's Norton - -	2,930	2,499	4	—	242	54	131
Martley - - -	483	428	—	—	44	3	8
Pershore - - -	389	352	—	—	34	1	2
Shipston-on-Stour - -	567	514	—	—	38	2	13
Stourbridge - -	3,446	2,998	—	—	379	5	64
Tenbury - - -	216	195	—	—	12	3	6
Upton-on-Severn - -	516	445	—	—	50	8	13
Worcester - - -	1,038	784	—	—	143	13	98
YORKSHIRE.							
East Riding.							
Beverley - -	759	637	1	—	72	5	44
Bridlington - -	539	456	3	—	57	4	19
Driffield - - -	699	606	—	—	79	3	11
Howden - - -	414	382	—	—	29	—	3
Kingston-upon-Hull -	2,907	2,472	5	—	306	14	110
Patrington - -	280	257	—	—	22	—	1
Pocklington - -	439	380	—	—	45	9	5
Sculcoates - -	3,542	3,017	6	—	370	23	126
Skirlaugh - - -	297	264	—	—	29	1	3
York - - -	2,328	1,974	6	—	255	3	90
YORKSHIRE.							
North Riding.							
Aysgarth - - -	156	131	—	—	16	1	8
Bedale - - -	250	227	1	—	20	—	2
Easingwold - -	282	263	—	—	17	—	2
Guisborough - -	2,150	1,830	3	—	197	14	106
Helmsley Blackmoor -	173	158	—	—	15	—	—
Kirkby Moorside - -	180	151	—	—	22	3	4
Leyburn - - -	253	223	—	—	24	2	4
Malton - - -	745	630	—	—	70	17	28
Middlesbrough - -	3,906	3,394	5	—	371	37	99
Northallerton - -	387	344	—	—	35	1	7
Pickering - - -	421	330	1	—	54	14	22
Reeth - - -	162	141	—	—	19	2	—
Richmond - -	402	363	—	—	31	4	4
Scarborough - -	1,241	1,087	1	—	107	20	26
Stokesley - - -	429	387	—	—	36	1	5
Thirsk - - -	407	359	1	—	30	3	14
Whitby - - -	896	775	—	—	89	24	8
YORKSHIRE.							
West Riding.							
Barnsley - - -	3,405	2,819	—	—	363	34	189
Bramley - - -	2,114	1,855	2	—	207	8	42
Bradford - - -	6,678	5,532	1	—	747	4	394
Bierley, North - -	4,765	3,993	—	—	548	21	203
Dewsbury - - -	5,661	3,031	2	1	756	42	1,829
Doncaster - - -	1,808	1,568	4	—	202	4	30

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
YORKSHIRE—*cont.*							
Ecclesall Bierlow - -	3,112	4,506	4	—	409	19	174
Goole - - -	683	591	1	—	72	5	14
Halifax - - -	5,902	5,195	2	1	554	55	95
Hemsworth - -	337	293	—	—	34	—	10
Holbeck - - -	1,047	915	2	—	113	1	16
Huddersfield - -	5,143	4,634	5	—	464	7	33
Hunslet - - -	2,413	2,120	1	—	258	4	30
Keighley - - -	2,023	802	—	—	291	1	929
Knaresborough - -	593	506	—	—	62	6	19
Leeds - - -	7,355	6,440	1	—	805	18	91
Ouseburn, Great - -	364	332	—	—	31	—	1
Pateley Bridge - -	280	253	—	—	27	—	—
Penistone - - -	632	547	—	—	65	10	10
Pontefract - - -	1,958	1,644	1	—	211	7	95
Ripon - - -	483	419	1	—	53	2	8
Rotherham - -	3,162	2,712	2	—	321	9	118
Saddleworth - -	730	618	—	—	63	1	49
Sedbergh - - -	154	132	—	—	16	—	5
Selby - - -	528	471	—	—	52	—	5
Settle - - -	436	391	—	—	39	3	3
Sheffield - - -	7,719	6,176	4	—	912	32	595
Skipton - - -	1,173	951	—	—	128	25	69
Tadcaster - - -	836	708	—	—	86	7	35
Thorne - - -	550	456	1	—	64	6	23
Wakefield - - -	3,534	3,033	—	—	350	8	143
Wetherby - - -	432	351	1	—	40	13	27
Wharfedale - -	1,655	1,366	—	—	189	20	80
Wortley - - -	1,416	1,208	1	—	130	11	66
ANGLESEY.							
Anglesey - - -	419	351	1	—	58	1	8
Holyhead - - -	574	491	—	—	55	4	24
BRECKNOCK.							
Brecknock - -	485	443	1	—	35	3	3
Builth - - -	284	251	—	—	27	1	5
Crickhowell - -	818	702	—	—	85	1	30
Hay - - -	322	282	—	—	38	1	1
CARDIGAN.							
Aberaeron - -	370	337	—	—	21	4	8
Aberystwith - -	749	652	—	—	65	12	20
Cardigan - - -	487	449	—	—	30	3	5
Lampeter - - -	306	268	—	—	30	3	5
Tregaron - - -	280	254	—	—	19	5	2
CARMARTHEN.							
Carmarthen - -	1,073	979	—	—	76	9	9
Llanelly - - -	1,749	1,595	—	—	138	—	16
Llandilo Fawr - -	574	531	—	—	40	—	3
Llandovery - -	449	406	1	—	35	5	2
Newcastle-in-Emlyn -	515	481	—	—	28	—	6

—	Births.	Successfully Vaccinated.	Insusceptible of Vaccination.	Had Small-pox.	Dead, Unvaccinated.	Vaccination postponed.	Remaining.
CARNARVON.							
Bangor and Beaumaris -	1,033	931	—	—	93	4	5
Carnarvon - -	1,395	1,196	1	—	171	12	15
Conway - -	471	410	—	—	39	13	9
Pwllheli - -	603	546	—	—	48	5	4
DENBIGH.							
Llanrwst -	400	343	—	—	44	4	9
Ruthin - -	404	363	—	—	37	1	3
Wrexham - - -	2,167	1,816	1	—	226	37	87
FLINT.							
Asaph, St. - - -	786	724	1	—	60	1	—
Hawarden - -	575	537	—	—	31	5	2
Holywell - - -	1,568	1,362	—	—	141	16	49
GLAMORGAN.							
Bridgend and Cowbridge -	1,455	1,277	—	—	130	8	40
Cardiff - - -	3,427	2,896	1	—	339	51	140
Gower - - -	343	285	—	—	41	13	4
Merthyr Tydfil - -	4,110	3,719	—	—	322	15	54
Neath - - -	2,213	1,982	—	—	169	19	43
Pontardawe - -	894	813	—	—	61	8	12
Pontypridd - -	3,776	3,086	2		471	42	175
Swansea - - -	3,882	3,368	1		346	28	139
MERIONETH.							
Bala - - -	170	147	—	—	18	1	4
Corwen - - -	498	403	—	—	63	7	25
Dolgelly - -	468	408	—	—	49	8	3
Festiniog - - -	945	811	—	—	109	18	7
MONTGOMERY.							
Llanfyllin - - -	609	543	—	—	56	1	9
Machynlleth - -	365	311	1	—	36	11	6
Forden - - -	587	517	—	—	54	6	10
Newtown and Llanidloes -	899	746	—	—	93	16	44
PEMBROKE.							
Haverfordwest - -	1,011	856	—	—	101	14	40
Narberth - - -	672	595	—	—	48	16	13
Pembroke - -	987	853	—	—	84	38	12
RADNOR.							
Knighton - - -	302	260	—	—	32	—	10
Rhayader - - -	223	184	—	—	14	1	24

No. 2.

App. No. 2.

Inspection of Public Vaccination.

List (alphabetically arranged) of 276 Unions inspected during the Year 1878, with reference to the Proceedings under the Vaccination Acts, 1867 and 1871, and an Account of the Awards made to the respective Public Vaccinators out of Moneys voted by Parliament for that Purpose.

Union.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award.		Range of Awards in each Union.		Total Sum awarded in the Union.	Inspector.
		1st Class Award.	2nd Class Award.	Minimum.	Maximum.		
				£ s. d.	£ s. d.	£ s. d.	
Abergavenny - -	3	3	—	7 10 0	37 13 0	68 9 0	Dr. Thorne.
Abingdon - - -	6	4	2	2 10 0	20 3 0	47 10 0	„ Stevens.
Albans, St. - -	4	2	—	16 15 0	20 4 0	36 19 0	„ Thorne.
Alresford - - -	2	1	—	—	—	7 5 0	„ Stevens.
Alton - - - -	4	3	—	7 1 0	11 2 0	28 9 0	Do.
Altrincham - -	6	4	—	6 19 0	31 15 0	55 4 0	„ Beard.
Alverstoke - -	1	1	—	—	—	42 4 0	„ Stevens.
Ampthill - - -	4	4	—	9 4 0	18 5 0	48 2 0	„ Thorne.
Andover - - -	6	4	—	2 3 0	14 18 0	34 14 0	„ Stevens.
Ashbourne - -	7	2	—	3 11 0	7 16 0	11 7 0	„ Beard.
Ashby de la Zouch -	6	1	—	—	—	24 1 0	Mr. Power.
Austell, St. - -	7	1	—	—	—	11 8 0	Dr. Blaxall.
Axbridge - - -	12	5	1	2 7 0	14 17 0	35 7 8	Do.
Axminster - - -	12	1	—	—	—	7 8 0	Do.
Aylsham - - -	7	3	—	5 0 0	8 15 0	19 3 0	„ Airy.
Bakewell - - -	8	2	—	2 10 0	4 19 0	7 9 0	„ Beard.
Barnet - - -	5	3	—	5 0 0	8 18 0	19 2 0	„ Thorne.
Barnstaple - -	10	5	1	2 12 0	22 17 0	53 6 0	„ Blaxall.
Barrow-in-Furness -	1	1	—	—	—	113 15 0	Mr. Power.
Barrow-on-Soar -	5	—	—	—	—	—	Do.
Barton Regis - -	6	5	—	14 11 0	79 17 0	172 9 0	Dr. Ballard.
Basford - - -	14	4	—	8 1 0	37 0 0	77 16 0	„ Beard.
Basingstoke - -	6	6	—	0 11 0	17 5 0	38 9 0	„ Stevens.
Bath - - - -	5	3	—	7 12 0	29 13 0	48 12 0	„ Blaxall.
Bedford - - -	8	5	1	4 8 8	32 2 0	80 11 8	„ Thorne.
Bedminster - -	9	2	2	2 15 0	13 6 0	23 14 8	„ Blaxall.
Bedwellty - -	6	4	—	10 8 0	54 0 0	139 11 0	„ Thorne.
Belper - - -	9	3	—	3 4 0	11 18 0	22 15 0	„ Beard.
Berkhampstead -	3	2	—	9 14 0	10 8 0	20 2 0	„ Thorne.
Bideford - - -	6	2	1	4 16 0	14 2 0	24 7 0	„ Blaxall.
Biggleswade - -	6	6	—	3 17 0	18 11 0	65 2 0	„ Thorne.
Billesdon - - -	3	1	—	—	—	11 2 0	Mr. Power.
Bingham - - -	4	4	—	4 8 0	10 3 0	25 13 0	Dr. Beard.
Birkenhead - -	2	1	—	—	—	33 14 0	Do.
Birmingham - -	1	1	—	—	—	271 5 0	„ Stevens.
Bishops Stortford -	7	5	—	2 17 0	14 0 0	32 16 0	„ Thorne.
Blaby - - -	3	2	—	14 18 0	27 7 0	42 5 0	Mr. Power.
Blackburn - -	10	4	—	9 9 0	32 1 0	92 7 0	Dr. Beard.
Blofield - - -	3	2	—	10 1 0	14 8 0	24 9 0	„ Airy.
Blything - - -	8	4	—	6 2 0	9 3 0	31 10 0	Do.
Bodmin - - -	7	3	—	3 5 0	7 15 0	15 14 0	„ Blaxall.
Bosmere & Claydon -	4	3	—	6 2 0	7 12 0	21 4 0	„ Airy.
Boston - - -	8	1	—	—	—	15 4 0	„ Beard.
Bourn - - -	7	6	—	2 7 0	7 5 0	27 2 0	Do.
Bradfield - - -	6	6	—	4 19 0	8 4 0	39 1 0	„ Stevens.
Brampton - - -	1	—	—	—	—	—	Mr. Power.
Bridgwater - -	10	1	1	9 9 0	16 12 0	26 1 0	Dr. Blaxall.
Bromsgrove - -	5	3	—	8 3 0	35 18 0	60 6 0	Mr. Power.
Buntingford - -	2	2	—	7 2 0	7 13 0	14 15 0	Dr. Thorne.
Bury St. Edmunds -	1	1	—	—	—	30 16 0	„ Airy.
Caistor - - -	10	—	—	—	—	—	„ Beard.
Camelford - - -	2	1	—	—	—	16 10 0	„ Blaxall

Union.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award. 1st Class Award.	2nd Class Award.	Range of Awards in each Union. Minimum.	Maximum.	Total Sum awarded in the Union.	Inspector.
				£ s. d.	£ s. d.	£ s. d.	
Carlisle	5	4	—	3 3 0	67 4 0	83 10 0	Mr. Power.
Catherington	1	1	—	—	—	5 12 0	Dr. Stevens.
Chapel-en-le-Frith	3	3	—	4 5 0	15 10 0	25 4 0	,, Beard.
Cheltenham	3	1	—	—	—	14 3 0	,, Ballard.
Chepstow	5	3	1	3 18 0	13 4 0	28 12 0	,, Thorne.
Chertsey	5	5	—	5 1 0	15 13 0	64 1 0	,, Stevens.
Chester	3	—	—	—	—	—	,, Beard.
Chesterfield	11	5	—	5 3 0	33 17 0	97 8 0	Do.
Chipping Sodbury	5	1	—	—	—	11 3 0	,, Ballard.
Chorlton	12	9	—	1 13 0	62 5 0	236 10 0	,, Beard.
Christchurch	2	1	—	—	—	34 17 0	,, Stevens.
Cirencester	4	4	—	1 9 0	20 8 0	41 8 0	,, Ballard.
Clutton	5	1	—	—	—	1 16 0	,, Blaxall.
Cockermouth	5	2	—	8 4 0	16 5 0	24 9 0	Mr. Power.
Columb Major, St.	6	4	—	5 16 0	9 15 0	33 9 0	Dr. Blaxall.
Congleton	4	3	—	5 13 0	21 2 0	44 18 0	,, Beard.
Cookham	4	2	—	1 6 0	6 7 0	7 13 0	,, Stevens.
Cosford	5	4	—	4 9 0	10 6 0	26 13 0	,, Airy.
Coventry	1	1	—	—	—	88 2 0	,, Stevens.
Crediton	11	2	—	1 5 0	1 7 0	2 12 0	,, Blaxall.
Croydon	7	6	—	3 7 0	80 0 0	138 0 0	,, Stevens.
Depwade	7	3	—	5 2 0	10 18 0	26 4 0	Dr. Airy.
Derby	2	2	—	36 0 0	45 11 0	81 11 0	,, Beard.
Docking	4	3	—	5 1 0	11 5 0	22 1 0	,, Airy.
Dorking	4	3	—	1 9 0	9 14 0	18 11 0	,, Stevens.
Downham	6	3	1	1 9 4	12 7 0	30 1 4	,, Airy.
Droitwich	6	3	—	5 2 0	18 7 0	30 13 0	Mr. Power.
Droxford	4	3	—	6 2 0	8 9 0	22 1 0	Dr. Stevens.
Dudley	8	7	1	27 17 0	70 6 0	332 19 0	Mr. Power.
Dursley	3	1	—	—	—	10 11 0	Dr. Ballard.
East Hampstead	4	3	—	4 6 0	10 10 0	23 18 0	Dr. Stevens.
East Retford	7	3	—	3 0 0	9 16 0	20 5 0	,, Beard.
East Stonehouse	1	1	—	—	—	40 15 0	,, Blaxall.
East Ward	6	2	—	3 13 0	7 19 0	11 12 0	Mr. Power.
Edmonton	13	9	—	0 15 0	19 4 0	103 7 0	Dr. Thorne.
Epsom	8	8	—	3 5 0	15 15 0	67 0 0	,, Stevens.
Erpingham	3	2	—	13 0 0	14 6 0	27 6 0	,, Airy.
Evesham	5	3	1	1 4 0	6 19 0	16 12 4	Mr. Power.
Faith, St.	5	3	—	2 19 0	7 8 0	15 18 0	Dr. Airy.
Falmouth	4	1	—	—	—	15 0 0	,, Blaxall.
Fareham	5	4	—	4 2 0	14 14 0	33 14 0	,, Stevens.
Farnham	7	4	—	3 11 0	30 9 0	51 2 0	Do.
Faringdon	4	2	—	4 6 0	12 11 0	16 17 0	Do.
Flegg, East and West	4	1	—	—	—	6 11 0	,, Airy.
Fordingbridge	2	2	—	7 11 0	9 11 0	17 2 0	,, Stevens.
Forehoe	6	5	—	0 10 0	10 3 0	20 0 0	,, Airy.
Freebridge Lynn	5	2	—	1 19 0	4 0 0	5 19 0	Do.
Frome	5	3	1	2 6 0	22 8 0	39 9 0	,, Blaxall.
Fulham	3	3	—	40 10 0	61 11 0	144 16 0	,, Stevens.
Gainsborough	8	4	—	1 16 0	8 0 0	17 18 0	Dr. Beard.
George's, St.	4	4	—	6 4 0	80 6 0	141 9 0	,, Stevens.
Germans, St.	6	2	—	4 16 0	8 2 0	12 18 0	,, Blaxall.
Giles, St., and George, St., Bloomsbury.	1	1	—	—	—	54 17 0	,, Stevens.
Glanford Brigg	9	7	—	3 16 0	12 7 0	53 15 0	,, Beard.
Glossop	2	—	—	—	—	—	Do.
Gloucester	2	2	—	20 16 0	75 6 0	96 2 0	,, Ballard.
Godstone	5	4	—	4 6 0	9 2 0	25 17 0	,, Stevens.
Grantham	7	3	—	2 18 0	6 0 0	14 8 0	,, Beard.
Greenwich	2	2	—	54 1 0	130 7 0	184 8 0	,, Stevens.
Guildford	9	9	—	2 11 0	17 11 0	71 6 0	Do.
Guiltcross	5	2	—	3 4 0	4 3 0	7 7 0	,, Airy.

Union.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award. 1st Class Award.	2nd Class Award.	Range of Awards in each Union. Minimum.	Maximum.	Total Sum awarded in the Union.	Inspector.
				£ s. d.	£ s. d.	£ s. d.	
Hambledon - -	5	4	—	4 16 0	12 8 0	29 14 0	Dr. Stevens.
Hampstead - -	1	—	—	—	—	—	Do.
Hartismere - -	5	3	—	8 9 0	12 12 0	32 16 0	„ Airy.
Hartley Wintney -	6	4	—	7 1 0	11 2 0	34 8 0	„ Stevens.
Hatfield - - -	3	1	—	—	—	2 13 0	„ Thorne.
Havant - - -	3	3	—	2 7 0	5 8 0	13 0 0	„ Stevens.
Hayfield - - -	1	1	—	—	—	18 8 0	„ Beard.
Helston - - -	4	2	—	5 10 0	19 17 0	25 7 0	„ Blaxall.
Hemel Hempstead -	4	1	—	—	—	6 16 0	„ Thorne.
Hendon - - -	7	2	—	3 1 0	19 3 0	22 4 0	Do.
Henstead - - -	4	2	—	4 0 0	6 4 0	10 4 0	„ Airy.
Hertford - - -	5	3	—	7 2 0	14 12 0	30 11 0	„ Thorne.
Hinckley - - -	5	4	1	2 8 0	27 7 0	52 10 4	Mr. Power.
Hitchin - - -	5	4	—	11 6 0	18 18 0	55 3 0	Dr. Thorne.
Holbeach - - -	5	—	—	—	—	—	„ Beard.
Holborn - - -	4	4	—	42 5 0	112 5 0	274 6 0	„ Stevens.
Holsworthy - -	5	1	1	3 12 8	5 6 0	8 18 8	„ Blaxall.
Honiton - - -	13	2	—	10 14 0	12 12 0	23 6 0	Do.
Horncastle - -	6	3	—	6 11 0	8 1 0	21 14 0	„ Beard.
Hoxne - - -	8	6	—	0 16 0	7 16 0	28 13 0	„ Airy.
Hungerford - -	5	2	—	6 7 0	6 10 0	12 17 0	„ Stevens.
Hursley - - -	1	1	—	—	—	7 1 0	Do.
Ipswich - - -	1	1	—	—	—	74 4 0	Dr. Airy.
Kensington - -	2	2	—	44 17 0	122 13 0	167 10 0	Dr. Stevens.
Keynsham - -	1	1	—	—	—	65 15 0	„ Blaxall.
Kidderminster - -	5	2	2	2 14 8	39 0 0	55 2 8	Mr. Power.
Kingsbridge - -	8	3	—	2 17 0	8 9 0	16 3 0	Dr. Blaxall.
Kingsclere - -	3	—	—	—	—	—	„ Stevens.
King's Lynn - -	1	—	1	—	—	14 10 0	„ Airy.
King's Norton - -	7	4	—	7 5 0	46 2 0	81 6 0	Mr. Power.
Kingston-on-Thames	11	6	—	3 4 0	18 4 0	40 17 0	Dr. Stevens.
Launceston - -	8	2	—	5 7 0	5 19 0	11 6 0	Dr. Blaxall.
Leeds - - - -	7	6	—	1 15 0	56 8 0	129 12 0	„ Stevens.
Leicester - - -	2	2	—	72 3 0	105 13 0	177 16 0	Mr. Power.
Leighton Buzzard -	2	1	—	—	—	2 8 0	Dr. Thorne.
Lincoln - - -	11	6	—	2 2 0	8 0 0	29 14 0	„ Beard.
Liskeard - - -	6	3	—	4 7 0	12 6 0	28 2 0	„ Blaxall.
Liverpool - - -	3	3	—	48 16 0	100 3 0	231 17 0	„ Stevens.
Loddon and Clavering	4	2	—	7 10 0	7 18 0	15 8 0	„ Airy.
Longtown - - -	2	—	1	—	—	2 11 4	Mr. Power.
Loughborough - -	4	4	—	4 6 0	35 11 0	67 17 0	Do.
Louth - - -	11	3	—	4 14 0	6 1 0	16 10 0	Dr. Beard.
Luton - - -	6	4	—	5 12 0	34 9 0	60 15 0	„ Thorne.
Lutterworth - -	5	2	1	2 4 8	4 19 0	12 2 8	Mr. Power.
Lymington - -	4	2	1	1 8 0	6 4 0	12 1 4	Dr. Stevens.
Macclesfield - -	6	4	—	1 3 0	22 4 0	32 16 0	Dr. Beard.
Manchester - -	3	3	—	53 11 0	57 5 0	166 5 0	„ Stevens.
Mansfield - - -	6	—	—	—	—	—	„ Beard.
Market Bosworth -	6	4	—	3 7 0	11 5 0	27 19 0	Mr. Power.
Market Harborough-	5	1	—	—	—	8 2 0	Do.
Martley - - -	6	—	—	—	—	—	Do.
Melton Mowbray -	6	1	—	—	—	7 18 0	Do.
Mildenhall - -	2	—	—	—	—	—	Dr. Airy.
Mitford & Launditch	9	4	—	1 0 0	9 19 0	29 4 0	Do.
Monmouth - -	6	2	—	5 0 0	38 2 0	43 2 0	„ Thorne.
Mutford and Lothingland.	3	1	1	22 4 0	23 6 0	45 10 0	„ Airy.
Nantwich - - -	8	2	—	6 2 0	16 6 0	22 8 0	Dr. Beard.
Newark - - -	10	3	—	1 13 0	3 4 0	7 9 0	Do.
Newbury - - -	3	—	1	—	—	4 10 8	„ Stevens.
Newcastle-on-Tyne -	3	4	—	28 11 0	47 3 0	137 15 0	Do.
Newent - - -	3	1	—	—	—	12 6 0	„ Ballard.
New Forest - -	5	4	—	1 1 0	12 13 0	25 14 0	„ Stevens
Newport (Mon.) -	8	7	—	3 8 0	78 12 0	18 10 0	„ Thorne.

Union.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award. 1st Class Award.	2nd Class Award.	Range of Awards in each Union. Minimum.	Maximum.	Total Sum awarded in the Union.	Inspector.
				£ s. d.	£ s. d.	£ s. d.	
Newton Abbot - -	11	4	—	5 4 0	13 4 0	39 3 0	Dr. Blaxall.
Northleach - -	5	3	—	2 16 0	6 13 0	14 5 0	" Ballard.
Northwich - -	7	5	—	1 12 0	30 7 0	78 7 0	" Beard.
Norwich - - -	1	—	—	—	—	—	" Airy.
Nottingham - -	2	1	—	—	—	67 1 0	" Beard.
Okehampton - -	6	2	—	9 5 0	14 15 0	24 0 0	Dr. Blaxall.
Olave, St. - - -	3	3	—	74 8 0	115 2 0	269 13 0	" Stevens.
Penrith - - -	6	2	—	6 3 0	6 12 0	12 15 0	Mr. Power.
Penzance - - -	5	3	—	8 10 0	20 18 0	41 12 0	Dr. Blaxall.
Pershore - - -	5	5	—	1 14 0	10 1 0	25 1 0	Mr. Power.
Petersfield - -	4	3	—	3 12 0	7 5 0	16 1 0	Dr. Stevens.
Plomesgate - -	6	5	—	5 16 0	8 3 0	32 9 0	" Airy.
Plymouth - - -	1	2	—	50 2 0	50 18 0	101 0 0	" Blaxall.
Plympton St. Mary -	5	3	—	8 8 0	10 19 0	50 5 0	Do.
Pontypool - - -	4	2	—	9 6 0	16 7 0	25 13 0	" Thorne.
Poplar - - -	4	2	—	50 9 0	108 8 0	158 17 0	" Stevens.
Portsea Island - -	2	2	—	84 18 0	101 18 0	186 16 0	Do.
Radford - - -	2	—	—	—	—	—	Dr. Beard.
Reading - - -	1	1	—	—	—	56 2 0	" Stevens.
Redruth - - -	6	5	—	12 18 0	22 3 0	81 16 0	" Blaxall.
Reigate - - -	4	3	—	5 10 0	24 0 0	41 14 0	" Stevens.
Richmond (Surrey) -	3	3	—	8 12 0	29 3 0	47 9 0	Do.
Ringwood - - -	1	1	—	—	—	13 10 0	Do.
Risbridge - - -	5	2	1	3 2 0	17 12 0	26 1 0	" Airy.
Romsey - - -	5	2	—	1 1 0	5 17 0	6 18 0	" Stevens.
Royston - - -	6	1	—	—	—	22 8 0	" Thorne.
Runcorn - - -	4	1	—	—	—	14 0 0	" Beard.
Salford - - -	3	2	—	84 17 0	140 9 0	225 6 0	Dr. Beard.
Samford - - -	5	3	—	0 17 0	11 13 0	21 11 0	" Airy.
Shardlow - - -	8	4	—	3 14 0	17 6 0	39 19 0	" Beard.
Sheffield - - -	6	6	—	12 11 0	53 16 0	187 13 0	" Stevens.
Shipston-on-Stour -	5	4	—	4 2 0	10 2 0	27 1 0	Mr. Power.[1]
Shoreditch - -	3	3	—	32 14 0	91 18 0	212 12 0	Dr. Stevens.
Sleaford - - -	7	—	1	—	—	9 6 0	" Beard.
Smallburgh - -	4	2	1	4 5 4	10 9 0	23 19 4	" Airy.
Southampton - -	2	2	—	42 4 0	47 11 0	89 15 0	" Stevens.
South Molton - -	9	3	1	0 14 8	4 7 0	11 9 8	" Blaxall.
South Stoneham -	5	3	—	7 10 0	17 5 0	41 17 0	" Stevens.
Southwell - - -	9	3	—	4 13 0	8 14 0	21 8 0	" Beard.
Spalding - - -	10	2	—	0 7 0	7 19 0	8 6 0	Do.
Spilsby - - -	7	4	—	5 4 0	9 16 0	28 16 0	Do.
Staines - - -	7	3	—	3 15 0	9 0 0	21 1 0	" Thorne.
Stamford - - -	7	3	—	2 15 0	9 2 0	20 11 0	" Beard.
Stepney - - -	1	1	—	—	—	87 18 0	" Stevens.
Stockbridge - -	2	2	—	6 11 0	8 5 0	14 16 0	Do.
Stockport - - -	5	1	—	—	—	21 16 0	" Beard.
Stoke Damerel - -	2	1	—	—	—	38 19 0	" Blaxall.
Stourbridge - -	7	5	1	10 8 0	37 4 0	146 17 0	Mr. Power.
Stow - - - -	8	5	—	2 10 0	10 13 0	33 8 0	Dr. Airy.
Stow-on-the-Wold -	2	2	—	7 15 0	8 6 0	16 1 0	" Ballard.
Strand - - -	1	1	—	—	—	44 12 0	" Stevens.
Stratton - - -	2	—	—	—	—	—	" Blaxall.
Stroud - - -	6	4	—	9 13 0	27 10 0	62 0 0	" Ballard.
Sudbury - - -	7	5	—	1 5 0	22 10 0	58 2 0	" Airy.
Swaffham - - -	6	3	—	2 19 0	8 6 0	14 18 0	Do.
Tarvin - - -	2	2	—	9 15 0	15 6 0	25 1 0	Dr. Beard.
Tavistock - - -	7	1	—	—	—	6 4 0	" Blaxall.
Tenbury - - -	2	1	—	—	—	7 5 0	Mr. Power.
Tetbury - - -	2	2	—	4 3 0	11 7 0	15 10 0	Dr. Ballard.
Tewkesbury - -	4	2	—	5 9 0	8 3 0	13 12 0	Do.
Thetford - - -	6	2	—	1 6 0	11 4 0	12 10 0	" Airy.
Thingoe - - -	8	4	—	3 2 0	9 9 0	20 18 0	Do.
Thomas, St. - -	16	4	—	2 9 0	9 8 0	22 17 0	" Blaxall.

APP. No. 2.

Inspection of Public Vaccination.

Union.	No. of Vaccination Districts in the Union.	No. of respective Vaccination Contractors recommended for Award. 1st Class Award.	2nd Class Award.	Range of Awards in each Union. Minimum.	Maximum.	Total Sum awarded in the Union.	Inspector.
				£ s. d.	£ s. d	£ s. d.	
Thornbury - -	4	3	—	1 2 0	13 18 0	25 14 0	Dr. Ballard.
Tiverton - - -	14	2	—	1 5 0	9 10 0	10 15 0	„ Blaxall.
Torrington - -	5	1	—	—	—	7 1 0	Do.
Totnes - - -	11	2	3	0 18 8	15 13 0	26 10 4	Do.
Toxteth Park - -	2	—	—	—	—	—	„ Beard.
Truro - - -	7	—	—	—	—	—	„ Blaxall.
Uppingham - -	4	2	—	2 18 0	11 17 0	14 15 0	Dr. Thorne.
Upton-on-Severn -	5	3	—	4 4 0	13 7 0	22 11 0	Mr. Power.
Uxbridge - - -	7	7	—	3 19 0	19 5 0	66 18 0	Dr. Thorne.
Wallingford - -	3	3	—	9 6 0	11 7 0	31 8 0	Dr. Stevens.
Walsingham - -	6	1	1	4 0 0	7 3 0	11 3 0	„ Airy.
Wangford - - -	2	1	—	—	—	20 15 0	Do.
Wantage - - -	5	1	—	—	—	6 15 0	„ Stevens.
Ware - - - -	8	5	—	2 2 0	7 16 0	21 7 0	„ Thorne.
Watford - - -	5	1	—	—	—	8 2 0	Do.
Wayland - - -	2	1	—	—	—	11 9 0	„ Airy.
Wells - - - -	4	2	—	10 3 0	14 3 0	24 6 0	„ Blaxall.
Welwyn - - -	1	1	—	—	—	4 19 0	„ Thorne.
Westbury-on-Severn	4	4	—	8 10 0	21 4 0	61 17 0	„ Ballard.
Westminster - -	2	2	—	25 2 0	30 19 0	56 1 0	„ Stevens.
West Ward - -	4	1	—	—	—	10 2 0	Mr. Power.
Wheatenhurst - -	2	2	—	7 15 0	10 0 0	17 15 0	Dr. Ballard.
Whitchurch (Hants)	3	1	—	—	—	1 11 0	„ Stevens.
Whitechapel - -	1	1	—	—	—	110 19 0	Do.
Whitehaven - -	6	—	—	—	—	—	Mr. Power.
Wight, Isle of - -	9	8	—	1 8 0	22 19 0	83 13 0	Dr. Stevens.
Wigton - - -	7	3	—	3 14 0	10 4 0	18 1 0	Mr. Power.
Winchcomb - -	2	1	—	—	—	13 18 0	Dr. Ballard.
Winchester, New -	4	4	—	5 6 0	26 6 0	46 14 0	„ Stevens.
Windsor - - -	3	3	—	7 3 0	35 19 0	61 7 0	Do.
Wirrall - - -	4	1	—	—	—	13 11 0	„ Beard.
Woburn - - -	3	3	—	5 19 0	10 15 0	22 16 0	„ Thorne.
Wokingham - -	4	4	—	6 11 0	15 17 0	41 18 0	„ Stevens.
Woodbridge - -	4	2	1	3 17 4	13 3 0	28 9 4	„ Airy.
Worcester - - -	1	1	—	—	—	42 14 0	Mr. Power
Worksop - - -	7	—	—	—	—	—	Dr. Beard.
Yarmouth, Great -	1	1	—	—	—	37 11 0	Dr. Airy.
Total - -	1,396	726	34			11,994 0 0	

No. 3.

Statistics of the National Vaccine Establishment and Educational Vaccinating Stations.

App. No. 3.

National Vaccine Establishment.

I.—Staff at end of 1878.

N.B.—The stations named in *italics* are Educational Vaccinating Stations, authorised by the Local Government Board.

—	Name.	Vaccinating Stations.	Days and Hours of Attendance.
Vaccinators supplying lymph for the public service, & salaried from the Parliamentary grant	1. Dr. R. Cory - -	*Surrey Chapel* -	Tues., Thurs.; 1.
	2. Mr. W. E. G. Pearse -	*Tottenham Court Chapel.*	Mon., Wednes.; 1.
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. Mr. Ellis S. Guest -	*Manchester* -	Monday; 2.
	2–5. Dr. Edmund Robinson.	*Birmingham* -	2. Monday - 3. Tuesday - 4. Wednesday 5. Thursday - 11.
	6. Dr. H. A. P. Robertson	*Bristol* - -	Wednesday; 10.
	7. Mr. Roger Parker -	*Liverpool* - -	Tuesday; 2.30.
	8. Mr. E. L. Webb -	*Pimlico* - -	Thursday; 10.
	9. Mr. J. Hawthorn -	*Newcastle-on-Tyne.*	Wednesday; 3.
	10. Mr. W. E. G. Pearse -	*Westminster* -	Tuesday; 2.
	11–12. Mr. W. A. Sumner	*Marylebone* -	Tuesday; 2. Wednesday; 10.
	13. Mr. C. T. Blackman -	*Whitechapel* -	Wednesday; 11.
	14. Mr. Frederick Holmes -	*Leeds* - -	Tuesday; 2.30.
	15. Dr. Edward Lynes -	Coventry - -	Tuesday; 12.
	16. Dr. Hugh Thomson -	*Glasgow* - -	Monday; 12.
	17. Mr. C. Harriot Roper -	*Exeter* - -	Thursday; 3.
	18. Mr. Robert W. Dunn -	*Strand* - -	Thursday; 11
	19. Mr. Matthew Brownfield	Bromley, Middlesex.	Tuesday; 3.
	20. Mr. John Broadbent -	Ancoats - -	Wednesday; 2.
	21. Mr. W. Skinner -	*Sheffield* - -	Tuesday; 3.
	22. Dr. A. C. Clarke -	Salford - -	Thursday; 2.
	23. Mr. N. Miskin - -	Waterloo - -	Tuesday; 2.
	24. Mr. T. F. Morrish -	Toxteth Park -	Tuesday; 11.
	25. Dr. J. O. Affleck -	*Edinburgh* -	Wednes., Sat.; 1.
	26. Dr. R. Cory -	*St. Thomas's Hosp.*	Wednesday; 11.30.
	27. Dr. D. C. McVail -	*Glasgow West*	Monday; 1.
Teachers of Vaccination not supplying lymph -	Dr. W. Husband -	*Edinburgh*	Wednes., Sat.; 12.
	Dr. R. D. Tannahill -	*Glasgow* - -	Mond., Thurs.; 12.

II.—Sources and Amount of Lymph Supply in 1878.

N.B.—The Stations named in *italics* are Educational Vaccinating Stations authorised by the Local Government Board.

—	Vaccinating Stations.	Number of Vaccinations performed at the Stations respectively.		Number of Charges of Lymph supplied from the Stations respectively.	
		Primary.	Re-vaccinations.	Charged ivory Points.	Charged Tubes each estimated as equal to 10 ivory Points.
Vaccinators salaried from the Parliamentary grant	1. *Surrey Chapel*	583	114	12,303	—
	2. *Tottenham Court Chapel.*	949	33	160*	911
	Total	1,532	147	12,463	911
Parochial and other Vaccinators not salaried from the Parliamentary grant, but contributing lymph at a fixed rate of payment.	1. *Manchester*	1,363	1	—	1,132
	2–5. *Birmingham*	5,388	45	—	3,879
	6. *Bristol*	568	—	—	—
	7. *Liverpool*	841	26	—	1,286
	8. *Pimlico*	467	28	—	716
	9. *Newcastle-on-Tyne.*	618	—	—	887
	10. *Westminster*	867	11	—	982
	11–12. *Marylebone*	2,160	120	—	1,051
	13. *Whitechapel*	1,370	34	—	601
	14. *Leeds*	1,134	—	—	329
	15. Coventry	1,059	1	—	1,444
	16. *Glasgow*	1,402	—	—	1,575
	17. *Exeter*	539	7	—	—
	18. *Strand*	554	5	—	—
	19. Bromley	1,277	34	—	598
	20. Ancoats	1,252	—	—	4,388
	21. *Sheffield*	1,208	—	—	775
	22. Salford	825	—	—	858
	23. Waterloo	665	10	—	1,694
	24. Toxteth Park	1,351	22	—	1,172
	25. *Edinburgh*	1,100	6	—	48
	26. *St. Thomas's Hospital.*	667	5	—	765
	27. *Glasgow West*†	29	—	—	8
	Total	26,704	355	—	24,188
	General Total	28,326	502	12,463	25,099

* This number includes 40 charged glasses, each estimated as equal to four charged ivory points.

† Commencing December 1878.

III.—Distribution of Lymph, 1878.

Number of applications :

From Medical Practitioners in England and Wales -	8,543
" " " Scotland - - -	201
" the Army - - - - - -	470
" the Navy and from the Emigration Department -	
" India and the Colonies - - - -	189
" Diplomatic and other Foreign Services - -	95
Total - -	9,590

Supplies sent out :—

Charged ivory points - - - - -	14,954
" squares of glass - - - - -	40
" capillary tubes - - - - -	22,096

No. 4.

ABSTRACT of MEDICAL INSPECTIONS made in 1878 with regard, generally, to the INCIDENCE OF DISEASE on particular places, and to consequent Questions concerning the LOCAL SANITARY ADMINISTRATION.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by Inspector.
1. Atherstone and Polesworth. (Warwickshire.) Population, 6,346. *Dr. Airy.*	Report of Medical Officer of Health.	Atherstone rural sanitary authority.	*Atherstone.*—Water supply chiefly from wells which are generally in danger of pollution from privies. Cesspits not emptied till they become a nuisance. Sewerage good. Danger of importation of infectious disease by tramps and bargemen. No hospital accommodation for cases of infectious disease. Long delay of sanitary authority to provide proper water supply and to deal with the removal of excrement. *Polesworth.* — Water from several sources (wells, spring, canal) liable to pollution. Cesspits not emptied till they become a nuisance.
2. Battle Registration District: parts of. (Sussex.) *Dr. Airy.*	Regis.-General's Returns	Battle rural sanitary authority.	High death-rate from diphtheria, especially in Ewhurst sub-district. Severe outbreak of diphtheria at Staple Cross, spreading probably by concourse of children at school. Impure water supply. Dangerous nuisances from cesspits. Want of proper slop-drainage in small villages and hamlets.
3. Burton-upon-Trent. Villages of Church Gresley, Newhall, and Swadlincote. (Staffordshire.) Population, 9,280. *Dr. Airy.*	" "	Burton-on-Trent rural sanitary authority.	Severe epidemic of scarlet fever in Church Gresley and Newhall, and of diphtheria in Rosliston, Castle Gresley, and Church Gresley. In Newhall, a mining population, with very bad water and no proper drainage. Filthy privies and pigstyes. In Church Gresley, miners and potters, at present ill-supplied with water. (New waterworks are projected.) Main sewerage good, but drain connexions complained of. No hospital for infectious diseases.
	" "	Swadlincote local board.	Prevalence of enteric fever, and epidemic of scarlet fever in 1877. Water good in quality and ample in yield, but part let run to waste, and the rest inconveniently delivered. Drainage into a filthy watercourse. Enteric fever in the houses lining this stream. No hospital for infectious diseases.
4. Carmarthen Rural Sanitary District. (Carmarthenshire.) Population, 25,117. *Mr. Power.*	Reports of Medical Officers of Health.	Carmarthen rural sanitary authority.	Sustained and fatal prevalence of infectious disease, especially of "fever." Neglect of requirements of health and decency by cottiers. Dwellings generally ill-constructed deficient in accommodation, ill-ventilated, damp, dilapidated, or ruinous. Water supply commonly exposed to risk of pollution. Deficient or ill-contrived privy accommodation. Absence of proper drainage. Abundance of nuisances of various sorts. Sanitary administration defective.
5. Dewsbury Registration District. Population, 124,286. *Dr. Thorne.*	Regis.-General's Returns and Reports of Medical Officers of Health.	- - - -	*District generally.*—Large general and infantile mortality. Excessive mortality from infectious diseases, notably enteric fever, and scarlet fever. "Fever" and diarrhœa endemic in the district. House accommodation for the labouring classes, with but few exceptions, so constructed as to prevent through ventilation, the majority of the houses being built back-to-back. Water-supply for some districts liable to pollution at its sources, and periodically fouled in the delivery mains during intermissions in the service. Means of sewerage and drainage in most districts very defective, causing pollution of streams and fouling of air in and about dwellings. Midden-privies everywhere a source of grave nuisance and of injury to health. In some localities nuisance from defective scavenging. Special nuisance in some districts from the storage of urine in close proximity to houses for the purpose of the cloth trade. General absence of any hospital provision for the isolation of cases of infectious diseases, and of efficient means of disinfection.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by Inspector.
5. Dewsbury Registration District—*cont.*	Regis.-General's Returns and Reports of Medical Officers of Health.	Dewsbury town council.	*Dewsbury Urban Sanitary District.* (Pop. 24,764).—Frequent occurrence of infectious diseases. Epidemic prevalence of enteric fever in first quarter of 1877. Many streets ill-planned, and in a greatly neglected state. Some of the dwellings unfit for human habitation. Many houses built without means of through ventilation. Water-supply subject to pollution at, and probably on its course from, the gathering ground. Supply intermittent and liable to be fouled by suction of filth into mains. Sewerage and drainage very defective and ill-ventilated. Midden-privies a source of great nuisance and danger to health. Urine stored about houses for trade purposes so as to cause nuisance.
	" "	Batley town council -	*Batley Urban Sanitary District.* (Pop. 20,871).—Frequent recurrence of infectious diseases. Epidemic prevalence of enteric fever in first quarter of 1877, probably due to pollution of the then water-supply. Houses in some localities unfit for habitation; many built without means of through ventilation. Water supply intermittent. Works of sewerage incomplete. House drains sometimes so constructed as to admit foul air into dwellings. Midden-privies so constructed and managed as to cause nuisance, and injury to health.
	" "	Liversedge local board	*Liversedge Urban Sanitary District,* (Pop. 11,103).—Scarlet fever severely epidemic in 1875, and very prevalent in 1877. Frequent recurrence of enteric fever. House accommodation in some parts filthy and quite unfit for human habitation; in others dwellings have no means of through ventilation. Some localities have defective or polluted water. Means of sewerage and drainage faulty in the extreme. Midden-privies a source of nuisance and danger to health. Great neglect in removal of refuse.
	" "	Heckmondwike local board.	*Heckmondwike Urban Sanitary District,* (Pop. 8300).—Enteric fever usually prevalent, and epidemic in first quarter of 1877. Some of the dwelling accommodation unfit for human habitation. Numerous houses have no means of through ventilation. Back-to-back houses rapidly on the increase. Water-supply liable to pollution at its source; service intermittent, and subject to be fouled by suction of filth into mains. Means of sewerage and drainage defective in the extreme. Midden-privies almost universally a source of nuisance and of danger to health.
	" "	Birstal local board -	*Birstal Urban Sanitary District,* (Pop. 6,044).—Death-rate from enteric fever high. Water-supply for some houses derived from wells liable to pollution. Public sewers insufficiently ventilated; house drains at times most inefficient. Midden-privies very generally a source of nuisance and of danger to health.
	" "	Gomersal local board -	*Gomersal Urban Sanitary District* (Pop. 4,003).—Extensive epidemic of enteric fever in 1873. Some wells subject to risk of pollution. Means of sewerage most defective. Houses so connected with sewers as to admit of foul air passing into them. Means of excrement and refuse disposal very faulty, and a cause of disease. Houses built back-to-back in violation of byelaws.
	" "	Birkenshaw local board	*Birkenshaw Urban Sanitary District,* (Pop. 2,833.)—Excessive mortality from enteric fever. Houses built back-to-back without means of through ventilation. No proper system of sewerage and drainage. Escape of sewer air into dwellings from private drains. Midden-privies a source of nuisance and of danger to health.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by Inspector.
5. Dewsbury Registration District.—*cont*	Regis.-General's Returns and Reports of Medical Officers of Health.	Mirfield local board -	*Mirfield Urban Sanitary District* (Pop. 9,959).—Death-rate from enteric fever high. Scarlet fever epidemic in 1877. Houses built without means of through ventilation, in violation of byelaws. Water-supply in outlying parts of the district scanty and at times polluted. Means of sewerage and drainage most imperfect, and often leading to fouling of air inside dwellings. Midden-privies a source of grave nuisance and of danger to health.
	" "	Ravensthorpe local board.	*Ravensthorpe Urban Sanitary District* (Pop. 2,910).—Enteric fever somewhat prevalent. Water-supply subject to pollution at its source, if not also in its course to the district; supply intermittent. Midden-privies so constructed as to cause nuisance and danger to health. Some houses built without means of through ventilation, in violation of byelaws. Recent great improvements as regards means of sewerage, drainage, &c.
	" "	Morley local board -	*Morley Urban Sanitary District* (Pop. 9,607).—General death-rate, and that from "fever," very high. Scarlet fever widely epidemic in 1873. Sewers most imperfectly ventilated; house-drains so constructed as to admit foul air into dwellings. Great nuisance at sewer outfall. Midden-privies a grave source of nuisance and of injury to health. Removal of excrement and refuse greatly neglected. Urine stored for trade purposes so as to cause much nuisance. House accommodation bad in many localities. Insufficient ventilation about houses; many dwellings built with no means of through ventilation. General sanitary administration defective.
	" "	Ossett-cum-Gawthorpe local board.	*Ossett-cum-Gawthorpe Urban Sanitary District* (Pop. 9,190).—Occasional outbreaks of enteric and scarlet fever. Houses in some parts built without means of through ventilation. Polluted water supply in outlying portions of the district. Some parts, notably so-called "private" streets, ill-sewered. Midden-privies a source of nuisance and of danger to health. Great neglect as regards removal of excremental and other filth. New works of water-supply and sewerage in progress.
		Thornhill local board	*Thornhill Urban Sanitary District* (Pop. 6,306).—Large mortality from enteric fever. Defective and polluted water-supply in outlying localities. Means of sewerage and drainage defective, and facilitating escape of foul air into dwellings. Means of excrement disposal a source of grave nuisance. In one portion of the district known as *Savile Town* the streets and houses are exceptionally well laid out and constructed.
	" ,	Soothill-Nether local board.	*Soothill-Nether Urban Sanitary District* (Pop. 4,927).—Very large mortality from enteric fever. Scarlet fever epidemic in 1875. Houses built back-to-back and without through ventilation, in violation of the byelaws. Means for the disposal of excrement and refuse a source of great nuisance and injury to health. Means of sewerage faulty, and so constructed as to admit sewer air into dwellings.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdictions Concerned.	Chief Facts reported by Inspector.
Dewsbury Registration District—*cont.*	Regis.-General's Returns and Reports of Medical Officers of Health.	Soothill-Upper local board.	*Soothill-Upper Urban Sanitary District* (Pop. 3,469).—General death-rate and death-rate from enteric fever very high. Some dwellings unhealthy from dampness and absence of through ventilation. Means of sewerage and drainage most defective. House drains facilitate escape of sewer air into dwellings. Midden-privies a source of nuisance and danger to health. Scavenging very imperfect. No Medical Officer of Health appointed.
6. Kilburn and St. John's Wood. (North London.) *Mr. Power.*	Local request - -	Marylebone and Hampstead Vestries. (Other sanitary authorities incidentally concerned.)	Considerable prevalence of diphtheria, much circumscribed as to place and time. Supposed relation to sewers disproved. Demonstration in detail that the disease had been distributed with milk from a particular dealer. Source of infection of the milk not traceable.
7. Knighton Registration District. (Radnorshire.) Population, 12,930. *Dr. Airy.*	Reports of Medical Officers of Health.	Knighton rural sanitary authority.	*In Presteign*, want of sewerage, and of supply of pure water. Present water supply from shallow wells polluted by soakage of filth from privies and cesspools. In the rest of the *Rural District* water supply abundant, but unprotected from pollution. Outbreaks of enteric fever from polluted water. Nuisances from slops, pigs, and farmyard drainage. Dwellings damp, ill-ventilated, dilapidated. Privies insufficient, ill-constructed, and ill-kept. No hospital for infectious diseases. Inefficient action on the part of the sanitary authority.
	" "	Knighton town council	Ill-ventilated unwholesome dwellings round the Castle Banks and in the "Cwm." Sources of water-supply good, but summer service intermittent. Sewers unventilated. Privy, pigstye, and slop nuisances in the Cwm. Scavenging inefficient. Nuisance from slaughter-houses. Churchyard full. No hospital for infectious diseases.
8. Loughton - - - (Essex.) *Mr. Power.*	Local complaint - -	Epping rural sanitary authority.	Prevalence among infants of a peculiar and fatal skin affection, locally attributed to the use for nursery purposes of a particular violet powder, samples of which had been found on analysis to contain arsenic. Details of symptoms in fatal and non-fatal cases. Consideration of the malady with reference to erysipelas, and with reference to the particular violet powder alleged to have been the cause of it. Occurrences of skin disease shown to have been associated in every instance with use of the particular powder. (*See* p. 31.)
9. Lymington - - (Hants.) Population, 4,295. *Dr. Airy.*	Local complaints - -	Lymington local board	Water supply entirely from wells mostly in danger of contamination from privies, cesspools, and pigstyes. Sewers old, shallow, insecure, unventilated. Nuisance at cutfall in river. Pollution of brook. System of excrement disposal (by privies with open cesspits) offensive and dangerous. Nuisance from slaughter-houses. Want of efficient action on the part of the sanitary authority.

Area of Inquiry and Name of Inspector.	Ground of Inquiry.	Jurisdiction Concerned.	Chief Facts reported by Inspector.
10. Pembroke - - (Pembrokeshire.) Population, 13,704. *Dr. Airy.*	Information from the Admiralty and from the Board's General Inspector.	Pembroke town council	*Pembroke.*—Houses at East End ill-built, ill-ventilated, and unprotected from damp. Water of good quality, but insufficient in quantity. Workhouse supply in danger of pollution. No proper system of sewerage. Casual drainage to millpond and "commons" brook; the latter a nuisance. Nuisances from privies and pigstyes. *Pembroke Dock.*—Surface drainage inefficient. Some of the streets unguttered. Water supply partly from springs and wells, (some of doubtful purity), and partly from rain-water tanks, Supply fails in dry seasons. Great want of sewerage. Nuisances from privies, pigstyes, and slaughter-houses. No hospital for infectious diseases. No building byelaws.
11. Plymouth - - (Devonshire.) Population, 73,599. *Dr. Blaxall.*	Local information -	Plymouth town council	Epidemic of diphtheria, reported to have been due to infected milk. Coincidence of the suspected milk service with the outbreak found to have but little significance. Personal communication the chief way in which diphtheria has spread. Various unwholesome local conditions noted in course of inquiry.
12. ,,	Memorial from inhabitants praying for inquiry into general sanitary condition of the town.	,, ,,	For many years high mortality among children from epidemics, and recently very fatal whooping cough. Typhoid fever habitually present, but recently in less degree. Much autumnal diarrhœa, less during recent years. Reductions ascribed to improved water service, &c. Marked incidence of mortality observed in certain unwholesome streets. Sewerage very imperfect and defective. No systematic ventilation of sewers or drains. General prevalence of excremental nuisances. Water supply plentiful and good. Dwellings overcrowded and otherwise unwholesome. No efficient means of isolation of cases of infectious disease, and sanitary administration in many ways defective.
13. Tredegar - - (Monmouthshire.) Population, 16,000. *Mr. Radcliffe.*	Regis.-General's Returns and threatened outbreak of enteric fever.	Tredegar local board -	Continued prevalence of fatal epidemic diseases. Much overcrowding of houses, partly from their diminutive size, partly from indiscriminate letting of lodgings, and partly from partitioning cottage houses, designed for one family only, between two families. Insufficient water supply. Very defective sewerage and drainage, both surface and deep, and means of excrement disposal imperfect. Much privy nuisance, and nuisance generally. Default of sanitary authority in the performance of its duties as to nuisances and works of sewerage, and neglect to carry out recommendations made by the same inspector (Mr. Radcliffe) in 1870.
14. Wrexham Registration District. (Parts of.) (Denbighshire.) Population, 8,576. *Dr. Airy.*	Report of General Inspector, and Regis.-General's Returns.	Wrexham rural sanitary authority.	*Wrexham Rural Sanitary District.*—Diphtheria frequent in wet clayey parts of district. Bad water supply, drainage, and excrement disposal at isolated houses. Inadequate provision for isolation of infectious disease.
	,, ,,	Wrexham town council	*Wrexham Urban Sanitary District.*—Severe and extensive outbreak of diphtheria, spread apparently by school concourse. Medical Officer of Health imperfectly acquainted with extent of the outbreak. Nests of unwholesome dwellings of the lowest class, with bad privy and pigsty nuisances. Good water supply. Efficient drainage. Pollution of lower course of brook by sewage overflow swelled with surface water.

No. 5.

App. No. 5.

On Special Mortality among Infants at Loughton, by Mr. W. H. Power.

Report on a Special Mortality among Infants at Loughton, in the Epping Rural Sanitary District, by Mr. W. H. Power.

On the 22nd March 1878, complaint was made by Mr. Octavius Deacon, of Golding's Hill, Loughton, to Mr. Secretary Cross, that a serious attack by skin disease of his own infant had resulted from the use for nursery purposes of violet powder, which on analysis by Mr. G. Jones, F.C.S., had been found to contain in large proportion white arsenic; and further, Mr. Deacon stated his belief that a large and fatal prevalence of skin disease among infants in Loughton had been due to the use in a similar way of violet powder of a like sort. This representation was referred by Mr. Cross to the Local Government Board. On 25th March, the Board received a communication from the clerk to the Epping Rural Sanitary Authority enclosing a statement by the Medical Officer of Health to the effect that a special mortality among infants in his district, already reported by him, had, he has now reason to believe, resulted from the use of violet powder impregnated with arsenic. Hereupon the present inquiry was ordered.

I lost no time in putting myself in communication with Mr. Deacon and with the several officers of the Epping Rural Sanitary Authority, and from them received every assistance in carrying out my inquiry. Especially am I beholden to Mr. Fowler, medical officer of health, who has supplied me with important information respecting the occurrences resulting in the mortality referred to; and to Mr. Bell, inspector of nuisances, who has accompanied and assisted me day by day during my investigations. To Mr. Lewis, district medical officer, and to other medical men practising in Loughton, my acknowledgments are also due.

The result of this inquiry is as follows :—

Since early March 1877, 29 infants and children in Loughton have been attacked by, and 13 have died of, a peculiar affection of the skin, that had been regarded as an anomalous kind of erysipelas. The disease was described to me by the mothers or others nursing the cases as presenting the following appearances :—

In fatal cases, a generally blackened condition of the skin of the groins and pudenda, which quickly became somewhat swollen and hard; this was frequently the first change observed. Occasionally there was a like condition of the abdomen about and below the umbilicus. The skin of the axillæ and folds of neck was another part in which blackening and swelling was commonly observed. Invasion of these several parts, when it occurred, was simultaneous. In some instances, vesication, variously described as "little white blisters," "yellowish bladders" or "bags of water" preceded or appeared about the same time as the blackness; in others, blackness with, or without, vesication was preceded, by a short interval, by a bluish red condition of the parts affected. The vesicles breaking discharged clear fluid, and left raw black surfaces, which did not, it would seem, take on suppurative or sloughing action. In no instance was a tense shining appearance of the skin spoken of; nor was there, except in one case, any tendency of the blackened condition of the surface to extend over the limbs or trunk. The constitutional symptoms seem to have been great restlessness, with fits of crying or screaming in the first instance, passing soon into a condition apparently of collapse in which the infant quietly died. The average duration of illness in these cases was four to five days.

In non-fatal cases, the symptoms varied much in severity. In almost all, blisters or bladders like those already spoken of formed between the folds of the groins, in the armpits, and in the neck. In some cases these vesications broke and formed black excavated sores, in the neighbourhood of which the skin became more or less indurated and discoloured. From some of the sores "cores came out," and all discharged

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yellowish matter. In milder cases, minute vesicles burst and left shallow sores that were little if at all discoloured, and that quickly healed under appropriate treatment. The constitutional symptoms do not seem to have been in any instance out of proportion to the local malady. In few, if indeed in any, cases were vomiting or purging prominent symptoms.

There has now to be considered—What has been the nature of the disease, and how did it come about? Has it been erysipelas as it was at first thought to be: or, has it been as recently alleged, skin-poisoning?

I. *As to erysipelas.* From the above account it appears by no means surprising that the malady in its graver cases (many of the slighter ones did not come under medical treatment) should have been regarded as a disease of the nature of erysipelas. It resembled that disease in several important features, and the constitutional symptoms, particularly of the fatal cases, might well have belonged to erysipelas itself. On the other hand it may be remarked that the malady in question seems to have differed from erysipelas as ordinarily observed in certain not unimportant particulars. There was not, so far as I can ascertain, any of that marked, tense, glistening or shining appearance of the skin, almost invariably present in erysipelas of infants; moreover, the affection had commonly no tendency to wander over the trunk and limbs in the manner customary with such erysipelas; but instead remained localised almost from the first, in each instance, in the parts of the body primarily affected by it. This appears to have been specially notable as regards those slighter cases not medically treated; in such the vesication and subsequent abrasion and induration of the skin was observed only in the folds of the neck, armpits, and genital organs. Nevertheless, before discarding the hypothesis of erysipelas, I thought it well to inquire whether there had been any typical erysipelas among infants or others in the parish; and whether the facts of the distribution of the malady in question could be explained on the supposition that those attacked had had conveyed to them erysipelatous infection. In this sense inquiry has result as follows:—

(1.) As to typical erysipelas. Except two cases, occurring in adults, one in October, the other in December 1877 (both it will be observed long after the earlier cases of the infantile malady), I cannot hear of any occurrence whatever in Loughton of ordinary erysipelas in persons of any age. Vaccination proceeded as usual, and no erysipelas or other disease was observed in connexion with it.

(2.) As to likely channels for erysipelas propagation, one kind only seems of importance as being in any degree probable, viz., the baby linen clubs of the parish. These, the church club and the chapel club, have been instituted for the purpose of affording their subscribers body and baby linen during the month subsequent to confinement. One rule common to both clubs provides that clothing thus acquired shall be returned properly cleansed and got up within five weeks from the date of loan; and hence it might have happened that, assuming the disease to have been erysipelas, babies' napkins imbued with specific contagion might have been returned to the club imperfectly cleansed or not properly disinfected, and have thus, on re-issue, conveyed to other infants the infection of that disease. Examination of the operations of these two clubs shows that during the last 15 months there have been ten boxes or bags of baby linen in circulation, and that of the 29 sufferers by the malady 17 have received club linen, while 12 have not. On the other hand 33 other infants have during the same period had baby linen from one or other of the clubs without ill result. The mothers of the 17 club-sufferers were, with 19 others, all of them members of the church club, the total operations of which during the period referred to are shown in detail in Table I.

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On Special Mortality among Infants at Loughton, by Mr. W. H. Power.

TABLE I.

Box.	Order of Issue.	Date of Issue.	Infant attacked.	Date of Return of Box.	Order of Return.
C.C.[7] -	1	13 Jan. 1877 -	Mid. Mar. 1877	18 Feb. 1877 -	1
" -	5	20 Feb. " -	No - -	26 March " -	4
" -	10	14 May " -	No - -	18 June " -	10
" -	33	11 March 1878 -	No - -	—	—
C.G.H.[2]	2	20 Jan. 1877 -	4 March 1877 -	26 Feb. 1877 -	2
" -	21	26 Oct. " -	26 Oct. " -	12 Nov. " -	21
" -	29	14 Feb. 1878 -	14 Feb. 1878 -	18 Feb. 1878 -	27
S.P.[1] -	3	14 Feb. 1877 -	2 March 1877 -	23 March 1877 -	3
" -	9	5 April " -	No - -	14 May " -	9
" -	12	4 June " -	5 June 1877 -	21 June " -	11
" -	14	30 June " -	1 July " -	6 Aug. " -	14
" -	34	14 March 1878 -	15 March 1878 -	—	—
C.G.H.[1]	6	21 Feb. 1877 -	Early Mar. 1877	27 March 1877 -	6
" -	11	28 May " -	No - -	12 July " -	13
" -	18	27 Aug. " -	No - -	1 Oct. " -	18
" -	23	26 Nov. " -	1 Jan. 1878 -	1 Jan. 1878 -	24
" -	27	Jan. 1878 -	14 Feb. " -	—	25
" -	30	18 Feb. " -	Mid. Mar. 1878	20 March 1878 -	30
" -	35	29 March " -	No - -	—	—
G.P.[1] -	7	22 Feb. 1877 -	No - -	26 March 1877 -	5
" -	15	2 July " -	2 July 1877 -	6 Aug. " -	15
" -	17	16 Aug. " -	16 Aug. " -	20 Sept. " -	17
" -	19	26 Sept. " -	No - -	5 Nov. " -	19
" -	22	23 Nov. " -	15 Nov. 1877 -	17 Dec. " -	22
" -	26	14 Jan. 1878 -	No - -	18 Feb. 1878 -	28
" -	32	7 March " -	No - -	—	—
S.P.[2] -	4	19 Feb. 1877 -	No - -	26 March 1877 -	7
" -	8	28 March " -	No - -	4 May " -	8
" -	13	4 June " -	No - -	9 July " -	12
" -	24	28 Nov. " -	22 Nov. 1877 -	17 Dec. " -	23
" -	25	31 Dec. " -	No - -	4 Feb. 1878 -	26
" -	28	13 Feb. 1878 -	No - -	18 March " -	29
" -	36	30 March " -	No - -	—	—
G.P.[2] -	16	3 July 1877 -	No - -	9 Aug. 1877 -	16
" -	20	27 Sept. " -	No - -	5 Nov. " -	20
" -	31	18 Feb. 1878 -	19 Feb. 1878 -	25 March 1878 -	31

The facts to be learned from the above table are not upon the whole suggestive of relation between the operations of the club and the attack of sufferers by the malady, and for the following reasons:—The four first sufferers, attacked almost simultaneously in March 1877, received each of them a separate box from the club, and in one instance only out of the four was the next reissue of the box associated with attack of the infant receiving it. Further, the interval between the issue of the box

and attack of the infant, in families invaded by the disease, varied very oddly, and in a way too not easily reconcilable with such incubation period as might have been anticipated of erysipelas under circumstances of conveyed infection. In 8, including the four first sufferers, it varied from two to four or more weeks; in 7 it was nil or one day only; while in two the infant was attacked before receipt of the box. Examination of the same sort as regards the movements of monthly nurses gave similarly negative evidence. Apparently the disease, whatever may have been its origin, has not been carried from case to case by means such as might have conveyed erysipelatous or allied infection.

II. *As to skin-poisoning.*—The malady from which the 29 infants have suffered has now to be dealt with in its relation to the particular violet powder that has been alleged to have been the cause of it. This powder had, in every instance that I myself investigated, been bought from one or other of two grocer's shops situated, the one in the High Road, the other at Baldwin's Hill, Loughton. From inquiries by Mr. Bell, inspector of nuisances, it would appear that of many shops in Loughton selling violet powder, these two, and these only, obtained such powder from a certain dealer in the East of London referred to by name by the medical officer of health in his statement already mentioned. Mr. Bell further ascertained that in Loughton this particular powder was sold by the retail tradesmen in small penny packets or boxes, each of which bore the name and address of the wholesale dealer in question. The facts of the connexion between the powder thus sold in Loughton and the prevalence of disease are as follows:—

1. Of the 29 sufferers, 27 had the particular powder in use at or about the date of attack. Of the remaining two, the mother of one had the particular powder in the house at the time the infant was attacked, but did not, so far as she can remember, use it; the other mother (whose infant suffered very slightly) had no powder at all, and and is of opinion that the soreness of her infant's neck was the result of pressure from the instruments used in delivery.

2. The sufferers with few exceptions (all of whom however had the powder) were grouped near to one or other of the two shops which alone in this extensive parish sold the particular powder in question.

3. Infants using the particular powder, and those alone, were attacked by the malady. This is shown in the following table, which is an abstract of the results of personal inquiry to this end respecting infants born in the parish during the half year ended March 1878. Except where otherwise stated, violet powder of some sort was used to every child, and (with certain exceptions to be considered in the text) only one kind of powder was in use to the several children attacked by the malady.

Table II.

Locality.	Date of Birth.	Date of Attack.	Violet Powder from one or other of the two Shops.	Remarks.
Forest Road -	2 Oct. 1877	No - -	No -	? Any powder.
Loughton Park -	4 Oct. „	No - -	No.	
High Road - -	5 Oct. „	No - -	No.	
Baldwin's Hill -	6 Oct. „	25 Oct. -	Yes.	
Epping New Road	15 Oct. „	No - -	No.	
Forest Road -	18 Oct. „	No - -	—	Born in a tent by roadside.
Forest Road -	21 Oct. „	No - -	No.	
Ash Green -	25 Oct. „	26 Oct. -	Yes.	
Forest Road -	26 Oct. „	No - -	No -	? Any powder.
High Road - -	1 Nov. „	No - -	No.	
High Road - -	7 Nov. „	31 Dec. -	Yes.	
Smart's Lane -	8 Nov. „	No - -	No.	
Baldwin's Hill -	11 Nov. „	15 Nov. -	Yes.	
High Road - -	14 Nov. „	No - -	No.	
Forest Road -	18 Nov. „	No - -	No -	Only lived 15 minutes.
Ash Green - -	20 Nov. „	22 Nov. -	Yes.	
Smart's Lane -	20 Nov. „	No - -	No.	
England's Lane -	27 Nov. „	1 Jan. 1878	Yes -	Habitually used starch.
Smart's Lane -	30 Nov. „	No - -	—	Left district.
Loughton Road -	16 Dec. „	No - -	No.	
Warren Hill -	24 Dec. „	No - -	No.	
Smart's Lane -	24 Dec. „	No - -	No.	
Baldwin's Hill -	29 Dec. „	30 Dec. -	Yes.	
Ash Green - -	30 Dec. „	14 Feb. -	Yes -	At first used powder from previous confinement.
Mutton Row -	30 Dec. „	No - -	No.	
Golding's Hill -	2 Jan. 1878	20 Feb. -	Yes.	
Trap's Hill - -	3 Jan. „	No - -	No.	
York Hill - -	5 Jan. „	No - -	No.	
Forest Road -	19 Jan. „	No - -	No.	
Forest Road -	30 Jan. „	No - -	No.	
Smart's Lane -	5 Feb. „	No - -	No.	
Warren - -	8 Feb. „	No - -	No.	
Baldwin's Hill -	10 Feb. „	14 Feb. -	Yes.	
Forest Road -	12 Feb. „	No - -	No.	
York Hill - -	17 Feb. „	19 Feb. -	Yes.	
Baldwin's Hill -	19 Feb. „	Mid. March	Yes.	
High Road - -	1 Mar. „	No - -	No.	
High Road - -	11 Mar. „	No - -	No.	
Golding's Hill -	13 Mar. „	15 March -	Yes.	

4. Further and detailed evidence confirmatory in a high degree of relation in the sense of effect to cause between the malady of infants and the use of the particular powder, could, were it necessary, be given in regard of most, if not all, of the cases attacked by the disease. But the following will suffice. They are also explanatory of the interval between birth and attack observed in certain cases recorded in the above and in the previous table.

E. W., born 6th October 1877; attacked 25th October. Mother states that for the first fortnight from birth she used for dusting the infant violet powder purchased at a distance. This being expended,

she obtained a packet of the particular powder from one of the two shops in the parish selling it. A day or two after using this fresh powder she noticed redness, blackness, and swelling of the privates and neck of the infant; in three more days it died. C. N., born 7th November 1877; attacked 31st December. Mother from infant's birth used for dusting it violet powder from a chemist near at home, and perhaps some also from a friend. On 29th December she attended her daughter in confinement and took with her her own infant. Here she used for both infants powder from one of the two shops referred to. On 30th December her daughter's, and on 31st December her own, infant was attacked. Daughter's infant died January 1st; her own recovered, but is much scarred. P. S., born 30th December 1877; attacked February 14. From birth until about February 11th the mother used violet powder remaining in the house since her last confinement; she also used starch. About the last-mentioned date she obtained some of the particular powder, and after using it perhaps three days noticed pimples on the groins, under the scrotum, under the arms, and at both sides of the neck. The pimples soon turned black, and became deep holes discharging much yellow matter. Used the powder a few days only; "did not like it:" "it was yellow;" burned it. Child recovered. E. D., born 2nd January 1878; attacked about 20th February. The mother used starch powder from infant's birth until two days before it fell ill, when, having no starch powder, she procured a packet of the particular violet powder. This was used two days only, but the infant suffered in the same way as P. S. It recovered, but is scarred. H. J., born 19th February 1878; attacked middle March. The mother at and after infant's birth used violet powder received as a present from London. The day before the infant was attacked she commenced using some of the particular powder recently purchased. The groins only were affected in this case; they became black and broke into sores. The use of the powder was discontinued as soon as the infant fell ill. On one occasion, however, it was used to a sister aged two years and four months; she suffered in like manner. Both children recovered. A. W., born 26th May 1877; attacked 9th June. The mother states that until the infant was 11 days old she had no powder at all. About 5th June she purchased a packet of the particular powder and used it to the infant in the ordinary way. On 9th June she noticed that the privates were swelled, and that white bladders as big as a hazel nut had formed thereon, as well as under the arms and around the neck. These changed colour and broke into deep wounds which discharged yellow matter. Cores came out from the sores under the arms. The use of the powder was discontinued after six days, and in about two months the infant was fairly well. Hereupon the mother recommenced the use of the particular powder, and the same night the infant was very restless and screamed a great deal. Next morning "the bladders were out again;" the powder was then burned. The child eventually recovered, but is deeply scarred about the scrotum, groins, neck, and armpits, as if by sloughing of the soft parts hereabouts. F. W., born 20th February 1877; attacked early in March. From birth the mother used violet powder from a chemist near at hand, but when the infant was about a fortnight old she bought, and used to the lower parts of its body only, a packet of the particular powder. Next day the infant broke out into sores about the navel and pudenda. The use of the particular powder was at once discontinued, and the infant shortly got well. Some months later the mother, being out of violet powder, again used the particular powder to the infant, and at once the sores reappeared. The powder was then burned. A. D.,

aged three years, was attacked about Christmas 1877 by varicella. During recovery, and while the pocks were dying away, she herself purchased a packet of the particular powder, which was then used for dusting the eruption about the pudenda. Almost at once the dying vesicles became sores which turned black and discharged matter: on healing they left scars. It is stated that in this instance the powder was used on one occasion only. T. C., born 15th August 1877. 36 hours after birth pimples and bladders formed about the privates and navel, which parts swelled, turned black, and became hard; no sores. Infant died 21 August. The particular powder was used in this instance from birth. Three months afterwards some of the remainder of this powder was used for dusting sores on the head, face, and arms of a sister aged four years who had recently suffered from measles. These sores became much worse and inflamed; those on the arms have left large scars.

Incidentally it is here shown that those parts only of infants' bodies to which toilet powder is ordinarily applied have been affected by the malady; and further that such application of the particular powder has been constantly followed in very few days by the symptoms complained of. Additional evidence respecting the shortness of the interval between application of the particular powder and the appearance of the symptoms attributed to it, is afforded by the fact that of 16 infants to whom this powder was applied from birth onwards no less than 10 were attacked in from one to four days. Nor is the conclusion, irresistible from the foregoing evidence, in any way weakened by the six instances in which the attack was not immediate; for there must have been a beginning to the mischievous quality of the powder bought at the shops of the vendors of the particular powder. These six cases were at the very commencement of the total series. All of them, and they were of various ages, from two to 20 weeks, fell ill at the same time, viz., early in March 1877. And though all of them it would appear had used more than one packet of violet powder from one or other of the two shops in question between birth and the commencement of illness, in more than one instance a fresh packet of powder is remembered to have been procured a day or two before attack. So far from weakening, these exceptions strengthen the conclusion; more than that, they seem to indicate that not until the end of February or early March of last year did violet powder bought at these two shops in Loughton possess hurtful properties.

Probably enough has been made out to satisfy any reasonable doubt that may have been entertained as to the connexion between the use in Loughton of the particular violet powder and the lamentable effects attributed to it. It will be observed that the evidence is absolutely independent of the nature of the irritating agent in the powder. Whether or not that agent may have been arsenic, as found by Mr. Jones in the specimens submitted to him by Mr. Deacon, matters nothing to the proof I have given of this connexion. But I have submitted to Dr. Dupré [Ap. 3rd, 1878] for analysis samples of the violet powder which I obtained from the mothers of three of the sufferers from the malady, and when Dr. Dupré's report is received I shall append it [see appended note B.] Meanwhile I annex a tabulated statement of the cases investigated.

NOTE A.

29 Cases dealt with in Mr. W. H. Power's Report respecting a Special Mortality among Infants in Loughton Parish.

	Locality in Loughton.	Date of Birth.	Date of Attack.	Result.	Remarks as to use of the particular Powder.	Reference to in Report, under		
						Table I.	Table II.	Detailed evidence.
1	Golding's Hill -	14 Feb. 1877	2 March 1877	Died 7 March 1877	Powder from one of the vendors of the particular powder used from birth onwards.	No. 8	—	—
2	Baldwin's Hill -	7 Dec. 1876	4 March ,,	Died 6 March ,,	Powder from one of the vendors of the particular powder used from birth onwards. Had four packets.	—	—	—
3	Baldwin's Hill -	20 Jan. 1877	4 March ,,	Died 8 March ,,	Powder from one of the vendors of the particular powder used from birth onwards.	,, 5	—	—
4	Baldwin's Hill -	17 Oct. 1876	Early March ,,	Recovered - -	Powder from one of the vendors of the particular powder used from birth onwards; fresh packet just before attack.	—	—	—
5	Baldwin's Hill -	20 Jan. 1877	7 March ,,	Recovered - -	Powder from one of the vendors of the particular powder used from birth onwards till attack; probably fresh packet just before attack.	—	—	—
6	Golding's Hill -	12 Jan. ,,	Mid. March ,,	Recovered - -	Powder from one of the vendors of the particular powder used from birth onwards till attack; probably fresh packet about time of attack.	,, 1	—	—

29 Cases dealt with in Mr. W. H. Power's Report respecting a Special Mortality among Infants in Loughton Parish—*continued.*

	Locality in Loughton.	Date of Birth.	Date of Attack.	Result.	Remarks as to use of the particular Powder.	Reference to in Report, under		
						Table I.	Table II.	Detailed evidence.
7	Ash Green - -	20 Feb. 1877	Early Mar. 1877	Recovered - -	Other powder till day before attack, then particular powder.	No. 13	—	F. W., page 36.
8	High Road - -	4 June ,,	5 June ,,	Died 8 June 1877	The particular powder used from birth.	,, 10	—	—
9	Pump Hill - -	26 May ,,	9 June ,,	Recovered - -	The particular powder on and after 11th day from birth. Was twice attacked.	—	—	A. W,, page 36.
10	Baldwin's Hill -	29 June ,,	1 July ,,	Recovered - -	No powder of any kind. Thought by mother to have had local injury at delivery.	,, 11	—	(Doubtful case.)
11	Baldwin's Hill -	30 June ,,	2 July ,,	Died 7 July 1877 -	The particular powder used from birth to attack.	,, 21	—	—
12	Baldwin's Hill -	— 1875	August ,,	Recovered - -	The particular powder exceptionally used to a chafed thigh.	—	—	—
13	Stoney Path - -	15 Aug. 1877	16 August	Died 21 Aug. 1877	The particular powder used from birth till death.	,, 22	—	T. C., page 37.
14	Baldwin's Hill -	6 Oct. ,,	25 October	Died 28 Oct. ,,	Other powder till day or so before attack, then particular powder.	—	No. 4.	E. W., page 35.
15	Ash Green - -	25 Oct. ,,	26 October	Died 30 Oct. ,,	The particular powder used from birth onwards.	,, 6	,, 8	—
16	Baldwin's Hill	11 Nov. ,,	15 November ,,	Recovered - -	The particular powder used till attack, then discontinued.	,, 24	,, 13	
17	Ash Green	20 Nov. ,,	22 November ,,	Died 30 Nov. 1877	The particular powder used from birth till death.	,, 30	,, 16	—
18	Stoney Path - -	— 1873	— November ,,	Recovered - -	The particular powder exceptionally used to sores following measles.	—	—	Sister to T. C., page 37.

29 Cases dealt with in Mr. W. H. Power's Report respecting a Special Mortality among Infants in Loughton Parish—*continued.*

	Locality in Loughton.	Date of Birth.	Date of Attack.	Result.	Remarks as to use of the particular Powder.	Reference to in Report, under		
						Table I.	Table II.	Detailed evidence.
19	Golding's Hill	— 1875	Xmas 1877	Recovered	The particular powder exceptionally used to sores from chicken pox.	—	—	A. D., page 36.
20	Baldwin's Hill	29 Dec. 1877	30 December ,,	Died 1 Jan. 1878	The particular powder used from birth till death.	—	No. 23	Infant of N.'s daughter, page 36.
21	High Road	7 Nov. ,,	31 December ,,	Recovered	Other powder till 29 Dec., particular powder at and after that date.	—	,, 11	C. N., page 36.
22	England's Lane	26 Nov. ,,	1 January 1878	Recovered	Starch only thought to have been used; but particular powder kept in house.	,, 16	,, 18	—
23	Ash Green	30 Dec. ,,	14 February ,,	Recovered	Powder remaining from previous confinement till a few days before attack, then particular powder.	,, 17	,, 24	P. S., page 36.
24	Baldwin's Hill	13 Feb. 1878	14 February ,,	Died 18 Feb. 1878	The particular powder used from birth till death.	,, 7	,, 33	—
25	Golding's Hill	2 Jan. ,,	20 February ,,	Recovered	Other powder used till two days before attack, then, for two days, particular powder.	—	,, 26	E. D., page 36.
26	Golding's Hill	13 March ,,	15 March 1878	Died 19 Mar. 1878	The particular powder from birth till illness.	,, 12	,, 39	—
27	Baldwin's Cottage	— Dec. 1875	Mid. March ,,	Recovered	The particular powder exceptionally used a day or so before attack.	—	—	Sister to H. J., page 36.
28	Baldwin's Cottage	19 Feb. 1878	Mid. March ,,	Recovered	Powder from London till day before attack, then particular powder.	,, 18	,, 36	H. J., page 36.
29	York Hill	17 Feb. ,,	19 February ,,	Died 22 Feb. 1878	The particular powder from birth	,, 36	,, 35	—

Note.—Nos. 3 and 4, 13 and 18, 4 and 12, and 27 and 18 occurred, in each instance, in the same household.

NOTE B.

Report on Three Samples of Violet Powder received from Mr. W. H. Power, April 4, 1878.

All the powders were of a very pale yellowish colour, and rather more gritty to the touch than ordinary violet powder; they were also appreciably heavier, bulk for bulk. Taking the weight of a given bulk of ordinary violet powder as 1, the same bulk of these powders would weigh about 1·25. Under the microscope they are shown to consist of potato starch mixed with a very considerable proportion of crystalline matter, among which regular octahedra (arsenious acid) can be distinguished. On burning they evolve a very powerful arsenical odour.

Chemical analysis showed them to consist in 100 parts of

	A	B	C
Starch with traces of other organic matter - -	37·58	34·56	36·76
Arsenious acid (white arsenic) - - -	50·34	51·40	48·94
Oxide of lead* - - - - -	1·07	1·16	0·83
Other mineral matters chiefly carbonate of magnesia	11·01	12·88	13·47
	100·00	100·00	100·00

A. Dupré.

Westminster Hospital, April 13, 1878.

* The exact combination in which the oxide of lead occurs has not been determined whether as carbonate or combined with the arsenious acid or in some other form.

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On Effluvium Nuisances, by Dr. Ballard.

No. 6.

Third Report in respect of the Inquiry as to Effluvium Nuisances arising in connexion with various Manufacturing and other Branches of Industry, by Dr. Ballard.

I propose in this Report* to treat of the industrial nuisances which arise from two classes of offensive businesses, namely, those businesses in which substances of mineral origin are dealt with, and businesses in which the substances dealt with are of mixed (animal, vegetable, or mineral) origin. But before doing so it is necessary that I should repair a few omissions in the two former Reports.

CONTENTS.

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* I am desirous of expressing my obligation to the following gentlemen for the assistance they have kindly afforded me by reading through various portions of this Report for the correction of technical errors, and also by making numerous valuable suggestions; viz., H. Hussey Vivian, Esq., M.P., of Hafod Copper, Works; J. Corbett, Esq., M.P., of Stoke Prior Saltworks, and Mr. Brydon, the manager of the works; Mr. Mactear, of St. Rollox Chemical Works; Colonel Gamble, of St. Helens; Mr. E. Muspratt, of Liverpool and Widnes; Dr. Hewitt, of Bealey & Co.'s Bleach Works, Radcliffe; Mr. V. De Michele, of Cliffe Cement Works; Mr. Trewby, of Beckton Gasworks; Dr. Hunt, of Bouck & Co.'s Tar Works, Manchester; Mr. Charles Lowe, of the Carbolic Acid Works, Reddish; Mr. J. Spiller, of Phœnix Aniline Works; Mr. Henry Doulton, of Lambeth Pottery Works; Mr. James Colquhoun, of Tredegar Iron and Coke Works; Mr. R. Le Neve Foster, Inspector of Mines; Mr. J. Glover, of Wallsend; Mr. Norman Cookson, of Howden Lead Works; Mr. E. G. Ballard, of Par Lead Works; Mr. Arnauld, of Rothschild's Gold Refinery; and Mr. List, of the Horsehair Works, Bunhill Row.

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On Effluvium Nuisances, by Dr. Ballard.

PART III.—*Addendum.*

THE MANUFACTURE OF HORSEHAIR.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 17, 1878	Laycock and Sons	Portobello, Sheffield.	—
June 18, ,,	Fraser - -	Glasgow.	—
Oct. 24, 1879	Wm. List and Son	Bunhill Row.	—
Nov. 25, ,,	Govan Hair Works (Cleland's).	Govan, Glasgow.	—
Dec. 12, ,,	Tomkins - -	Hackney Road.	—
,, ,, ,,	Blyth - -	Bethnal Green Road.	—
,, 22, ,,	Kolle and Co. -	Glemsford, Suffolk.	—
,, ,, ,,	Churchyard -	Long Melford, Suffolk.	Size-making.

Descriptions of hair used.

Three descriptions of strong hair, namely, horsehair (manes and tails), cowhair, and pig's hair, are received for manipulation at establishments such as these, and are prepared for use for different purposes, such as the manufacture of horsehair cloth or seating, the stuffing of chairs, the manufacture of brushes, &c. The manes and tails of horses are derived from England, South America (chiefly Buenos Ayres), Australia, and Russia. The best horsehair comes from English stables, and consists of combings of the horses' manes and tails; the next best from Australia and South America, believed to have been cut from healthy, vigorous animals, and the next in quality comes from Russia (chiefly, as I understand, from Siberia). The hair of the mane is shorter, weaker and less elastic than that of the tail. Foreign hair comes into the market packed in bales of strong cloth. Bales of South American hair are very large, weighing sometimes half a ton, and are bound

round with hoop-iron ; the hair is packed tightly in these bales with the aid of hydraulic pressure. The Russian hair is packed into bales of about a quarter the size of the South American bales; being packed by hand, the bales of Russian hair are less tightly packed than those of American hair ; there is also an external covering of matting upon the Russian bales. There is another difference which, in view of the subject matter of this Report, is important, namely, that whereas in bales from other sources the hair from the manes and tails is mixed in the same bale, the hair from the manes and that from the tails is packed separately in the case of the Russian hair, the manes being packed together in one bale and the tails in another bale. The mode in which Russian hair (or at any rate much of it) is, as I am informed, collected appears important to be mentioned. It is gathered from all available sources by the peasants, and is sold in small parcels to individuals who collect it at fairs &c. These persons make it up into larger parcels and sell it to merchants. The result of this is that hair, as it reaches the merchant, is the mixed produce of innumerable places in the district where it was originally collected. As it reaches the merchant it is known as "raw" hair. This raw hair is sorted at St. Petersburgh, the long hair being made up into bundles or "dollies," into which some of the short hair is commonly stuffed to increase the weight. Of late years more raw hair (raw manes and raw tails) has been imported into England than formerly was the case.

Cowhair is derived from the same localities as horsehair. It is as a rule superior in quality to the manes of horses, and is used to mix with that hair.

Pig's hair is chiefly imported from Cincinnati and Chicago. It is strong and elastic, that of lean pigs being the best.

Some horsehair (tail) and cow's hair that I have seen has had attached to it portions of skin and sometimes portions of the bony structure of the animal's tail. All horse and cow's hair is more or less dusty, some of it very dusty and dirty. Russian manes vary much in this respect. All the samples that I have seen have been dusty, but some of the raw manes were so filthy that I did not like to touch them : they were mixed with bits of straw, &c. and masses of filth (dung, dried blood, &c.) were concreted upon the hair. Pig's hair is invariably dirty ; the dirt about it consisting chiefly of scurfy or cuticular matter. The dirtiest pig's hair is that imported from Germany.

Process of manufacture.
Sorting.

Any attached pieces of bone and skin having been cut off, the first process to which horsehair and cowhair are subjected is "sorting ;" the object of which is to separate long hair from short hair, and the coloured hair (whether long or short) from the white or whitish hair. Russian horsehair requires little sorting, inasmuch as the tail (long) and the manes (short) hair are in separate bales ; but some sorting is necessary, because the colours are mixed, and, as will appear presently, hair of different colours is somewhat differently treated. The sorting room is provided with tables, at each of which is a sorter, who is usually a woman. An opened bale stands beside the sorter, who takes a handful of hair out, lays it upon the table and sorts it into coloured and uncoloured, long and short hair. Much dust is separated from the hair in this process.

The subsequent manipulation, which short hair destined to be "curled" and long hair destined to be used for weaving, brush making, &c., severally undergo, differs essentially.

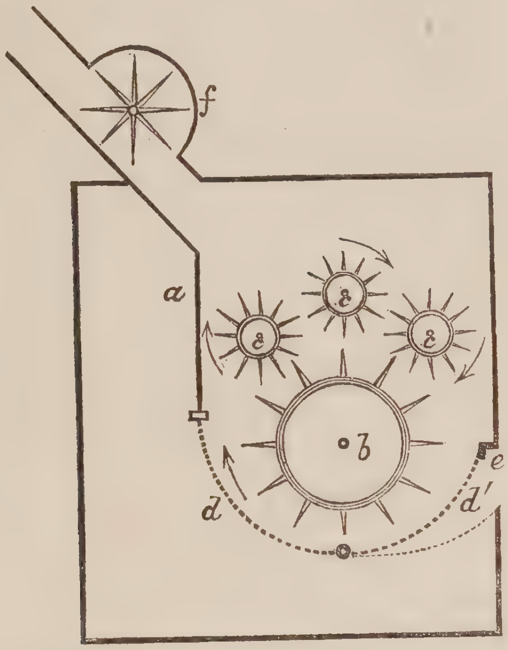
Manipulation of short hair.

Short hair, whether it be pig's hair, horsehair, or cowhair, if it be very dirty, is, in some establishments, first deprived of its dirt and dust in a dusting or "willowing" machine, the essential points in the con-

Dusting.

struction of which are shown in the rough diagram Fig. 1. It is a wooden box or enclosure *a*, about 8 feet high by 4 feet wide. Within

Fig. 1.



this are three iron cylinders, one large below (*b*) and three small above it (*c*), all of which cylinders are provided on the surface with iron spikes, and are made to revolve by steam machinery. Below the cylinders is a semicircular false bottom made of strong wire like a sieve (*d*, *d′*), the fore part of which *d′* is hinged to the back part *d* so as to be capable of being raised into the position shown in the drawing, or of being made to fall to the position shown by the faint dotted line. The forepart of the false bottom being let down, a parcel of hair is introduced at the opening *e* and is torn and teased, being caught up by the spikes of the cylinders as they revolve in the direction shown by the arrows. Except during the feeding or removal of the hair the fore part of the false bottom is raised, as shown in the diagram. The coarse dirt, with the broken hair, falls through the false bottom into the lower part of the box, whence it is from time to time removed by hand through a door at the back part of the machine. The fine dust diffused within the box, and which otherwise would pass out into the workroom, is drawn off by means of a fan *f* and disposed of in various ways at different establishments. At some establishments the dust is discharged into the air by means of a wooden channel opening on the roof of the workshop, at others into a wooden flue terminating in a box or chamber where the fine dust is collected, and from which it is from time to time removed in bulk. The dust collected in the dusting box and in the dust chamber is valuable as a manure, and is purchased by dealers. Some such dust collected in Glasgow finds its way even to London for manufacture into manure. But it is not all horsehair manufacturers who purchase hair so dirty as to require this dusting to be performed as a first process, and the dusting may only be performed as a first process when the hair is white and is not destined to be dyed.

Dyeing.

When short hair is to be dyed, the dyeing is (after sorting) usually the first operation it undergoes. It is performed by boiling the hair by means of free steam, in water with logwood, to which after some hours copperas (sulphate of iron) is added. This boiling is conducted in a vat or tank, open or covered, and the process occupies about six hours. The time occupied in the dyeing is longer in the case of white or grey hair than in the case of dark coloured hair. During the boiling the dust and filth

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about the hair are softened, loosened, and to a certain extent separated from it. The dyed hair is then removed from the tank to another vessel, where it is well washed by means of appropriate machinery (differing in different works) with hot water. It is then dried. If it have not been previously "willowed," it is now usually passed through a mill or carding machine similar in general construction to the dusting or willowing machine described above, in which any dusty matter remaining in the hair is separated; this machine also serves to card the hair if it requires carding, or to mix various kinds of hair in due proportions to meet the demands of customers, if it requires mixing. This machine discharges the hair upon the floor at the rear.

Curling.

The hair prepared in the various ways mentioned is now transported to the "curling" room. Here, by means of machinery similar to that of a ropery, it is made into a slightly-twisted rope, and by a second process it is twisted more tightly, the rope being then reduced to half its former length; and, by a third process, the rope is twisted into a convoluted coil; this twisting gives the hair the "curl" which is required. In order to fix the curl, the knots of convoluted rope are now steeped for several hours in cold water, after which they are baked in ovens. At some works, instead of steeping the coils, they are boiled or steamed before being baked. When the curl has thus been fixed, the ropes are untwisted by means of another machine, and the "curled" hair is then adapted for the stuffing of chairs, &c.

Manipulation of long hair.

Long hair is treated differently. Whatever its colour, it is taken from the sorting-room into a room where it is soaked and well washed in a tank of warm or cold water, at some works with the addition of soap and soda crystals; when it is dry it is hackled by drawing it through a number of long iron spikes fixed upon a board, to remove the short hair mixed with it (which then is used for "curling,") and then taken to another room to be drawn by hand into lengths. This process need not be further described. The hair is tied up into bundles, according to its length, the longest hair being destined for weaving, and the shorter pieces for brushmaking or other purposes. The coloured hair is dyed much in the same way as the short coloured hair; but the process is not continued for so long a period, lest the hair should be made "tender," and thus unfit for weaving or the other purposes to which it is to be applied. The white hair is not dyed, but is bleached, for some purposes, by exposing it for a sufficient length of time to the fumes of burning sulphur in a small closet constructed for the purpose.

Nuisance.

The only offensive odour, perceptible outside the works, that I have heard complained of as arising from such establishments as these, has its source in the steam issuing from the tanks in which pig's hair is boiled, whether with water for its preliminary cleansing or with logwood and copperas in the dyeing process. The nuisance is one very readily obviated, as it is obviated at Messrs. List's works by covering the tank with a close-fitting cover, and conducting the steam, by means of a pipe of sufficient capacity, into the chimney shaft.

Injury to health: production of "Authrax."

But a far more serious matter is the danger which exists of the production of fatal disease by the dusty matters given off when hair infected with the contagium of the disease known as "anthrax," "malignant pustule," "charbon," or "Siberian plague" is manipulated. In this country the principal danger in this respect attaches to the use of Siberian manes. The danger of the work-people contracting disease is present in every stage of the manipulation up to the time when the hair arrives at the dye vat. Persons who unpack the bales, who sort the hair, who are engaged in the room where the dusting process is con-

ducted, and those who draw long hair into lengths, are the persons chiefly exposed to the danger. But the danger from the infected dust is not limited to them, nor even to the hair workers in the establishment where infected hair may be received. Infected dust, discharged into the atmosphere outside at the roof of the works, as it sometimes is, may be carried away by the wind, and may produce the specific disease in persons whom it may reach at a greater or less distance from the spot where it is discharged. Evidence of this is furnished in Dr. Russell's valuable communication on the subject, which forms part of this volume (Appendix No. 7) and which should be read with this Report. Perhaps the most striking example of such an occurrence is that afforded by the last of the series of cases which he records as having occurred at the Adelphi Works in Glasgow. This case was that of a woman who was a fur cutter, and who worked in a building separate from that in which the infected horsehair was manipulated, and at a place 70 feet at least distant from the spot at which the dust, which Dr. Russell believes to have caused the woman's illness, was discharged into the atmosphere. The building was part of and within the curtilage of the establishment; but so far as my argument is concerned, it might have belonged to an entirely different establishment. Had this been so, it is not unlikely that the origin of the woman's illness would have remained a mystery. The dust, as mere dust, would probably not have been sufficient in quantity to have constituted a nuisance or to have attracted particular notice. But the danger is not limited even to the vicinity of the works where the hair is manipulated. I have pointed out that the dust collected in the dusting machine, or in an appropriate chamber, is transmitted sometimes to a distance to dealers in manurial matters. Is it going too far to suggest that some of the cases of blood-poisoning of mysterious origin, which we meet with occasionally in London and elsewhere, may possibly have arisen from some casual exposure to the influence of this kind of infected dust?

Prevention of disease.

Russian hair coming regularly into the market without restriction, the question arises how it can be dealt with prior to or during the ordinary manufacturing manipulation, so as to render it safe to the work-people and to others who may in any way be exposed to infection from it or from the dust which is removed from it in its manufacture. The principal desideratum is a process of disinfection which can be applied to short or long hair, whether coloured or white, without injuring it for its intended purposes, and which shall be of such a nature as shall work in with the process of manipulation now followed, and interfere with it as little as possible. From the mode in which the hair is packed tightly in bales, it is clear that the hair cannot be disinfected satisfactorily until it is taken out of the bales, and this taking out may be a source of danger. The danger might be reduced by the workman covering his mouth and nose with an appropriate respirator, and by wearing at the time gloves and clothes kept for the purpose at the works and disinfected with chlorine or sulphurous acid or by baking at the end of each day's operations, as well as by personal ablutions before meals and on leaving work. The cloths and matting of the bales should be burned. As respects short hair (manes), the process of willowing before dyeing should in all cases be abandoned, and the hair should be emptied directly from the bales into the dyeing tank. This suggestion involves of course the abandonment of the process of sorting the short hair. As to this last point, I am strengthened by the opinion of Mr. List, than whom it will be admitted by the trade that no man is more fitted by experience and his antecedents to speak with authority. Conversing with him upon the subject, he said that it would be no hardship upon manufacturers to require them to

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abandon the preliminary sorting of Russian manes, and to require the whole contents of the bales, coloured and white hair together, to be put into the dyeing tank.* This dyeing, from the heat employed and the materials used, is an effective disinfecting operation. After the hair has been dyed in the way described it can no longer be dangerous to work. As respects the long hair (tails) it appears to me that some of the ordinary disinfectants might be added to the water in the tank in which it is washed. Mr. List, to whom I suggested the use of carbolic acid or bleaching liquid (chloride of lime) in this way, thought that they would be likely to injure the hair and make it tender. I should like to see some experiments made in relation to this subject. Unquestionably the dust from the willowing machine ought under all circumstances to be burned. In all works the dust should be drawn away by a fan or otherwise from the box which encloses the apparatus, and be discharged into the ashpit of a fire, where it may be consumed.

This subject of disinfection and prevention of disease is fully discussed in Dr. Russell's communication.

PART IV.—*Addenda.*

THE MANUFACTURE OF WOOD-PULP FOR PAPER-MAKERS.

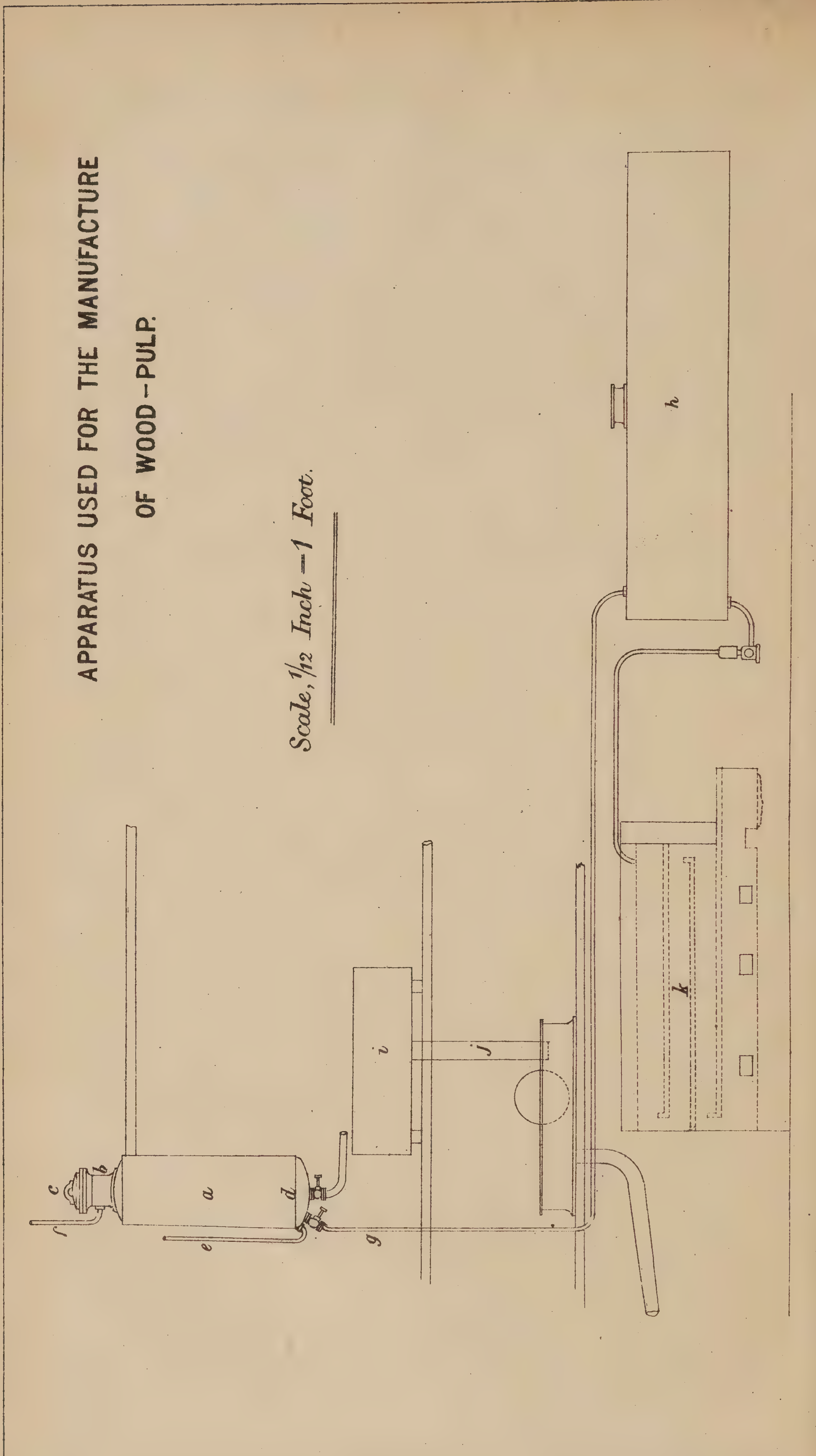
Establishment visited.

Establishment visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 28, 1879	The Mersey Wood-pulping Company.	Bootle - -	Manufacture of clogs.

During the last year I received several communications from Dr. Sprakeling, the Medical Officer of Health for Bootle, respecting nuisances arising from this establishment, and asking me for any information I could give him about the trade. All I could say was that I knew nothing about it, but would take an opportunity of visiting the works in the progress of my inquiry into trade nuisances. I was unable to visit the works before February, 1879, and in the meantime the Urban Sanitary Authority had taken proceedings before the magistrates on two grounds, only the latter of which was upheld, viz., first, on the ground that it was such an offensive business as required the sanction of the Sanitary Authority for its establishment, and that this sanction had not been obtained, and secondly, on the ground of its occasioning nuisance, and that the best practicable means of abating the nuisance had not been used. It appeared from the evidence that a similar business had formerly been carried on by another company (but under the same manager) in another part of Bootle, and had produced a great nuisance, for which proceedings had been instituted. I failed to discover by the inquiries I made that this process is carried on anywhere else in the country, though I learned that it had been carried on at various times elsewhere, but that the works had after a time been given up. The proceedings taken against the Mersey Wood-pulping Company appear to

* Mr. List, however, desires me to call attention to a fact which is calculated to throw an impediment in the way of this disinfection, namely, that the horsehair supplied under contract for the use of the Navy is required to consist wholly of undyed hair.



Dangerfield Lith. 22 Bedford St Covent Garden

have had some good effect, since when I at length visited the works I found that improvements had been effected calculated to do away with much of the nuisance complained of.

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Process of manufacture.

The process as I saw it conducted, and which Plate I. (reduced from a plan furnished me by Mr. Jones, the manager of the works,) illustrates, is as follows:—The material used consists of the shavings and chips from the hard wood (birch and beech) used for the manufacture of clogs. This material, after having been disintegrated, is introduced into an iron cylinder or digester *a*, situated in an upper chamber which is ventilated by louvre openings at the sides of the roof. There are four digesters situated there; each is 12 feet deep and 5 feet in diameter, having at the upper end a neck *b* about 18 inches high. The opening at the top is covered with a dome-shaped cover *c*, which during work is fastened down firmly by screws and nuts. It has a perforated false-bottom *d*, a steam-pressure gauge, and a cup of mercury in the cover for the thermometer. The charge of wood is 35 cwt., and after being introduced through the top of the digester, 120 cubic feet of a solution of caustic soda of the strength of 7° Beaumé (sp. gr. 1·048) are run in. The cover is now screwed down, and steam is thrown in by the steam-pipe *e*, and is kept on for 1½ or 2 hours. The steam is then turned off, and in order to economise heat, and now also to prevent nuisance, the waste steam under pressure within the cylinder is discharged by a pipe *f* into the next cylinder, newly charged, where it is condensed by the cold cylinder. The lid is now loosened, when a little steam escapes into the building, and the liquor is drained off by the pipe *g* to a close iron tank *h* (in this case boiler-shaped) for storage. Cold water is then run into the cylinder in order to wash the pulp, and the washing water is run off into the storage tank. The cylinder is a second time filled up with cold water, and the whole contents, liquor and pulp together, are discharged into an open iron draining tank *i*, situated on a lower floor. The discharged matter is still warm enough to emit a good deal of vapour, which finds an exit at the roof of the building. From the strainer, the liquids from which are run off into the drains, the pulp is passed down a shoot *j* into a washing machine similar to that used at paper-works, where it is made to circulate while being washed; and the pulp is finally run off, drained and dried in a centrifugal machine preparatory to being packed. The finished material is known in the trade as "half-stuff." The liquor collected in the storage tank is subjected to a process for recovery of soda, similar to the process adopted for the recovery of soda from esparto liquor (2nd Report, page 102). The apparatus used is indicated at *k*. The fumes from this apparatus are conducted into a chimney shaft 100 feet high. I examined the material when drawn in the treacly condition, and I found that the vapour emitted from it in that stage of the process was not nearly so offensive as that from esparto liquor in the same stage of recovery. The evaporated liquor is pretty thoroughly calcined before the charge is drawn, and the calcined material is deposited in a den, where it burns out and cools, but it does not form such a rocky substance as is formed when esparto liquor is similarly treated.

Nuisance and its abatements.

The vapour proceeding from the strong liquor produced in the digester has an offensive odour somewhat similar to that given off during the process of making oxalic acid from sawdust (2nd Report, p. 99), but not so powerful; and the vapour from the washing waters and discharged pulp, has a similar odour, but of course less strong. It appears that formerly, when the digesters were opened, all the steam under pressure was allowed to escape into the building, and passed out by the louvres, thus creating part of the nusiance complained of; and it is not impossible that a similar nuisance might recur even now, if the workmen were

negligent. The steam issuing from the storage tank *h* was also formerly discharged by a 1 foot square wooden channel carried up from it to about the level of the top of the neighbouring houses, and was a source of additional nuisance. There is now an iron pipe leading from it to a flue which receives furnace gases, &c., and discharges them into the chimney. A third source of nuisance appears to have been the escape of offensive vapours and gases from the inlets of house drains and street drains communicating with the town sewers, into which hot liquors from the works used to be run off. The adoption of the soda-recovery process appears to have remedied in great measure this source of offence. The only evidence of health having been injured by the effluvia proceeding from the works consisted in that given at the hearing of the summonses, and was that of persons who said that they were nauseated and made to vomit.

PREPARATION OF "AMMONIA MATERIAL" FOR GASWORKS.

Establishments visited.

ESTABLISHMENTS VISITED.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
April 16, 1878	Alum and Ammonia Company.	Battersea.	—
June 25, ,,	William Marriott -	Birmingham.	—

Process.

This process consists in the saturation of wood sawdust with sulphuric acid for the production of a material used at some gasworks for the separation of ammonia from the crude gas (p. 116). After the material has been used at the gasworks it is taken back and subjected to other processes, either for the separation from it of the sulphate of ammonia it then contains, or in order to prepare it in some other way for use by the manufacturers of artificial manures. At the Battersea works there is a large and lofty chamber in which many tons of sawdust are stored, and in which the saturation of it with acid is carried on. This is effected by means of a square covered channel about 12 or 18 inches wide, in which a screw works and moves the sawdust through it into a second lofty chamber, where the material is stored. As the sawdust passes through the above-mentioned channel it receives upon it a little stream of sulphuric acid. The effect of the acid is to blacken the sawdust and to cause the evolution of acid fumes, partly consisting of sulphurous acid and partly of acetic acid, the odour of which latter predominates. At one time, the acid vapour emitted from openings in the reception or storing chamber were so powerful and disagreeable that serious complaints arose. To obviate these the chamber was closed up as I found it at the time of my visit, and was made to communicate with a coke tower or scrubber, down which water was made to trickle, the vapours being drawn off from the chamber and through the tower by means of a fan, and discharged into a chimney shaft about 70 feet high. The material as it is returned from the gasworks may contain, I am informed by Mr. Marriott, junr., as much as 50 per cent. of sulphate of ammonia, and from 5 to 10 per cent. of sulphocyanide of ammonium. Formerly, I was informed, the material, when received back from the gasworks, used to be exposed in the yard in order to permit of the escape into the atmosphere of various offensive hydrocarbonaceous matters which it had

absorbed, and which had to be got rid of before it could be used for making sulphate of ammonia. The sulphate was afterwards dissolved out and crystallised. This was an offensive process, and I was informed at the works that it has now been given up: the crude material, after being merely deprived of the offensive hydrocarbons, is now sold off the premises to the manure makers. The method adopted to effect this deodorisation inoffensively, was at the time of my visit as follows:—There were two close chambers, each about 20 feet square and 10 feet high, lighted from the roof, and provided with flues beneath the floor in order to heat them. A channel from the upper part of each chamber conducted the offensive vapours to a fire, where they were consumed. This alteration has, I learn, been successful in obviating nuisance. The material is brought from the gasworks in covered carts. At Marriott's works in Birmingham the process of preparing the sawdust is similar to that in use at Battersea. The returned sawdust is heated on a floor with flues beneath. The vapours that arise pass out at the roof, but no complaint has been made of them, so far as I have been able to learn. It is supposed that some at least of the offensive vapours pass downwards into the flues and are carried off to the chimney, but I could not satisfy myself that the arrangements adopted really acted in this way.

Prevention of nuisance.

Part V.—On Effluvium Nuisances arising in Connexion with Branches of Industry in which Mineral Substances are principally dealt with.

BRICK-BURNING.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Jan. 19, 1876 -	Thomas & Co. -	Avonside, Bristol	(Hofmann's kiln.)
Feb. 12, ,, -	In a field -	Warrington -	(Clamp burning.)
May 22, ,, -	Ditto - -	Leeds - -	(Ditto.)
June 8, ,, -	Steel - -	Reading -	(Scotch kilns, closed kiln.)
Oct. 18, ,, -	Campbell -	Stoke-on-Trent -	(Closed kiln.)
April 9, 1878 -	Edward Brooke and Sons.	Huddersfield -	(Closed kiln.) Manufacture of salt glazed ware.
Nov. 14, ,, -	A. W. Stroud -	Acton - -	(Clamp burning.)
,, ,, -	Wright - -	Ditto - -	(Ditto. Scotch kiln.)
,, 19, ,, -	Burham Cement and Brick Works.	Burham, near Maidstone.	(Ditto, ditto.) Manufacture of Portland cement. Lime burning.
,, 22, ,, -	Various brick-fields.	Faversham -	(Clamp burning.)
,, ,, -	Whiting - -	Ditto - -	(Scotch kiln.)
,, 23, ,, -	Various brick-fields.	Sittingbourne -	(Clamp burning.)
Dec. 12, ,, -	E. C. Gibbons & Co.	Shotley, near Ipswich.	(Scotch kiln.) Manufacture of Portland cement.
,, 13, ,, -	Patrick - -	Dovercourt -	(Ditto.) Ditto.
,, 17, ,, -	Harbour Extension Works.	Portsmouth -	(Hofmann's kiln.)
Jan. 14, 1879 -	Dowlais Iron Works.	Dowlais, South Wales.	(Close kiln.) Iron smelting.
,, 22, ,, -	Doulton & Co. -	Old Hill, Worcestershire.	(Ditto.) Manufacture of salt glazed ware.
Feb. 25 ,, -	Ditto - -	St. Helens, Lancashire.	—
Mar. 4 ,, -	Bradbury -	Basford, Stoke-on-Trent.	—

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
April 2, 1879	Hartley - -	Castleford -	Manufacture of salt-glazed ware.
„ 3 „ -	Leeds Brick-making Co.	Armley, Leeds -	—
„ 3 „ -	George Lax -	Leeds -	—
„ 5 „ -	Darfield Pottery Works.	Darfield, Yorkshire.	Manufacture of salt-glazed ware.
May 13 „ -	J. C. Edwards -	Cefn, Denbighshire.	Salt glazing of blue bricks.
„ 13 „ -	Ditto - -	Ruabon.	Man. of salt glazed ware.
At various times	Other brickyards	In Black Country of South Staffordshire and elsewhere.	—

Process of brick-making.

Various clays, differing in geological age, in colour, hardness, and other physical characters, and in chemical composition (especially in respect of organic and peaty matter they contain) form the basis of the materials out of which bricks are manufactured. About London and at Sittingbourne, Faversham, and other places, a natural mixture of clay and sand, technically known as "brick-earth," is preferred. The preparation which the material undergoes before being made into bricks also varies in different places with the character of the material itself, and the kind of brick which it is purposed to make from it. The following may be taken as the ordinary method of making what are known as clamp-bricks (*i.e.*, bricks which are subsequently to be burned in clamps) in and about London and the brick-making districts of Kent. The preparation commences in the winter, during which season the brick-earth is dug and mixed with chalk and fine ashes. These ashes are the siftings from the contents of the dust-bins of London houses, and consist of the finer particles of coal and breeze (cinders), mixed inevitably with saline matters from the burned coal and with organic matter both of vegetable and animal origin. (See p. 309.) Mr. A. W. Stroud informs me that for the ordinary kinds of bricks made about London, 20 chaldrons of ashes and 15 tons of chalk are mixed with every 100 yards (*i.e.*, 2,700 cubic feet) of brick earth. At the Burham works, near Maidstone, where the basis of the ordinary clamp bricks is a red clay which lies below the chalk and above the blue clay (gault), out of which the Portland cement is manufactured, the preparation of the "turf," as it is there termed, is as follows:—A heap is made of successive layers of clay (which contains chalk enough for the brick-maker's purposes), sand, and ashes in the following proportions, viz., 1 foot in depth of clay, 2 inches of sand, and $\frac{3}{4}$ inch of ashes, and these layers are repeated until a heap about 10 feet in height is formed. The heap is left to become "weathered" until the spring, when it is dug down, and the materials the heap consists of are well mixed together. Mr. A. W. Stroud informs me that the finer kinds of bricks are known in the London trade as, 1. "Cutters" (used for cutting for the corners of windows, &c.); 2. "Yellow seconds"; 3. "Pale seconds"; 4. "Pickings"; and 5. "Paviours," the "builders' paviours" being of harder and the "paving paviours" of softer quality. In making the mixture for these bricks, more chalk, say about one-third more, is used than for the more inferior bricks known as 6. "Common stocks"; 7. "Grizzles," and 8. "Place-bricks." In making the inferior kinds of bricks, the mixture of the materials is made by hand, and it then passes at once to the pug-mill; but the mixture for the superior

bricks is first passed through a mill supplied with water, from which mill the "washed" material is run off into a square reservoir or "back" varying in size, but usually about 6 feet deep, built up of banks of clay and lined with inferior bricks loosely laid. In this back the watery mixture forms a deposit; the water above is run off, and the deposited matter is then passed through the pug-mill. In other parts of the country I have noticed clamp-bricks made without any admixture of fuel into the substance of the bricks. When bricks are to be burned in kilns, it is not usual to mix ashes with the material, but at the Burham works I found that coke dust instead of ashes was mixed with the material, except in the instance of "cutters," where no coke dust was used, but an increased quantity of sand was added. In the Black Country, about Dudley, at St. Helens, &c., the hard clays dug from the marl pits have first to be crushed down and disintegrated by appropriate machinery, after which they are pugged with water supplied in just sufficient quantity to bring them to the proper consistence for moulding. For inferior bricks the upper red clay of the marl pits has ground up with it portions of rocky material found lying in the clay. The brick material prepared in the ways described is moulded into bricks either by hand labour or by machinery, and the "green" bricks having been dried in the open air, or on a drying floor heated by flues beneath it, are now ready to be burned.

Bricks are burned either in what are termed "clamps" or in "kilns."

1. Clamp-burning.

1. *Clamp burning.*—A clamp is a quadrangular pile, systematically but loosely built up of "green" bricks, placed layer upon layer until the desired height is attained. It is constructed thus: an even piece of ground is selected, and upon it bricks are laid in an open manner as a first layer. "Breeze" (cinders and small pieces of unburned coal from London dust bins) is thrown on this, so as to fill up the spaces between the bricks and form a layer about $5\frac{1}{2}$ inches in thickness. Upon this another layer of "green" bricks is laid pretty closely, then $2\frac{1}{2}$ inches more of "breeze," then a third layer of bricks, and then an inch of breeze, above which the clamp is built up layer upon layer to the extent of 33 layers, which thus form a clamp about 9 or 10 feet high. In making the foundation of the clamp, passages of about 2 bricks in height and 6 or 8 inches wide, extending through the base of the clamp from one side to the other, are left at intervals of 8 or 9 yards. Against the outer openings of these little passages small fires of wood and coal are made, and thus the breeze is ignited. The burning of the breeze serves merely to initiate the process, which is subsequently continued by the slow combustion of the combustible matter mixed into the substance of the bricks themselves. A clamp may be of any size. Clamps are commonly made to burn at one time from half a million to a million and a half of bricks. When all or nearly all the combustible matter is consumed the ignition ceases. It ceases first towards the outside, and last at the inside of the clamp. A clamp may be so arranged that, while burned bricks are being removed from one end, fresh green bricks are being built up at the other end.

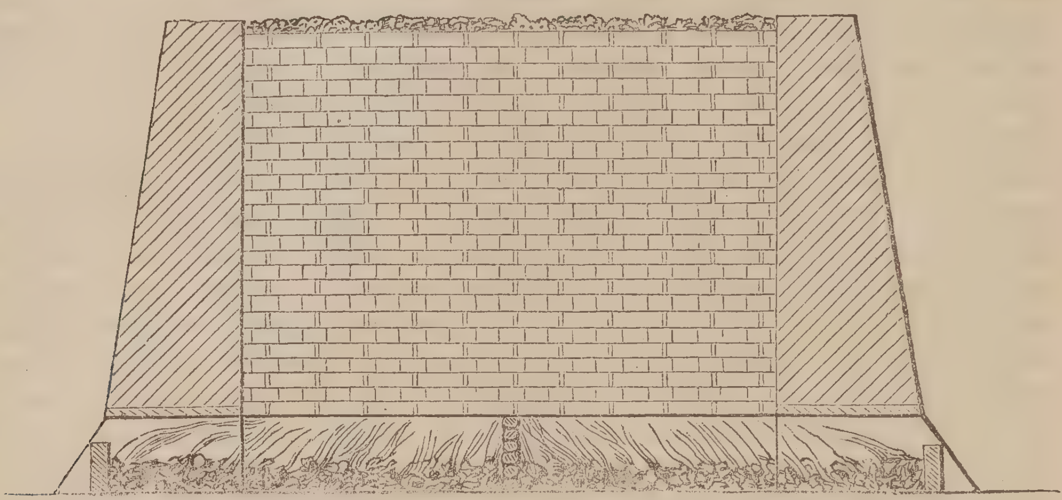
2. Kiln-burning.

2. *Kiln burning.*—I have stated above that, as a rule, no combustible matter is incorporated into the brick material when this kind of burning is going to be adopted. Hence there arises the necessity of the constant expenditure of fuel during the whole process of burning. The fuel invariably used is coal. Kilns may be described under two heads, viz., open kilns and closed kilns: or kilns which, being open above, permit the smoke and other effluvia to pass off at the top; and kilns which, being closed in at the top, do not permit of this, but from which the smoke and other effluvia are carried away by a flue and discharged elsewhere.

Open kilns.

a. Open kilns.—The most common form of open kilns is what is known as the "Scotch kiln." Fig. 2 represents, in transverse section, the essen-

FIG. 2.

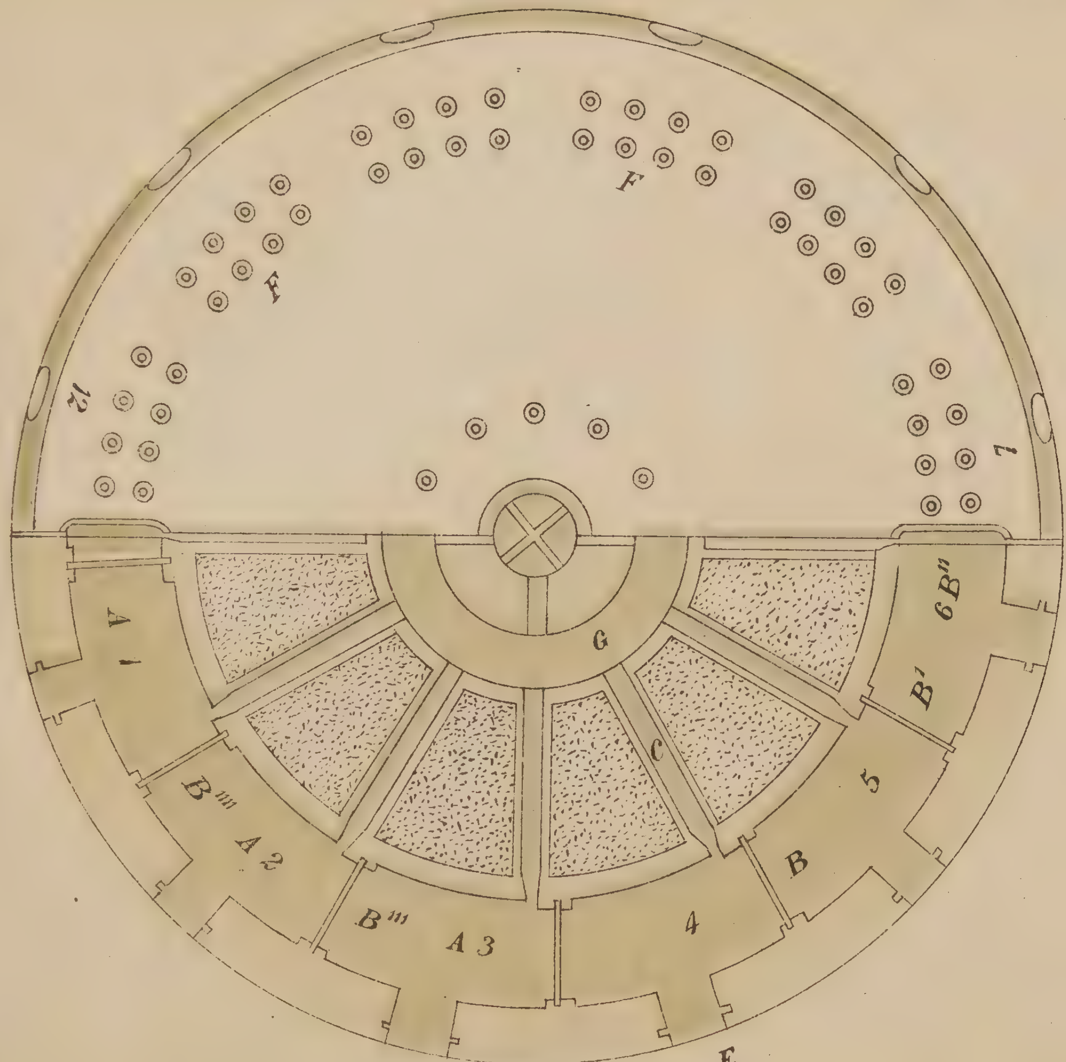


tial points of construction of the "Scotch kiln." An oblong space is enclosed to the requisite height by side and end walls, a space about 8 or 9 feet wide being left vacant in the middle of the two ends to allow of access to the interior. The "green" bricks are built up so as to fill the enclosed area, but so too as to leave channels or passages through the kiln from side to side at the base, corresponding to which extemporised passages are permanent opposite openings in the side walls. These passages are commonly about 2 feet 3 inches high and 9 inches wide, and are put at intervals of about 2 feet 6 inches. They are in fact fire-places, the open ends of which are partly built up from the bottom with bricks to retain the fuel, leaving a small space above for stoking and admission of air. The open spaces in the end walls are, prior to lighting the kiln, plastered up with clay to exclude the air. Such kilns may be of any convenient size, but I am informed that the largest dimensions readily workable are 80 feet in length and 20 feet in width. At first lighting, a fierce fire is not desirable, the object being to get rid of the moisture, but when this has been effected, *i.e.*, in about 100 hours, earth is loosely laid over the top of the kiln to keep in the heat, and the fires are got fully up. The bricks are usually fully burned at the end of the next 100 hours, and then the fire holes are completely bricked and plastered up until the fires are extinguished. At the end of another 130 hours, or thereabouts, the kiln may be discharged. This kiln may be variously modified in details. Another kind of open kiln consists of a chamber, either circular or rectangular, with an arched roof, provided with one or more openings in it for the escape of smoke and vapours at the top. Such a kiln is heated with coal introduced into fire-places placed at intervals round the base of the kiln, having again corresponding extemporised passages left in the foundation of the mass of "green" bricks. There is an entrance opening in the kiln on one side, which opening is temporarily built up when the kiln has been filled. In a modification of this kiln there is an open-work fire-brick floor, with fires in passages beneath it. In any kind of open kiln the smoke and the heated air pass from the bottom of the kiln upwards through the mass of bricks, and are discharged at the top. At the Dowlais Ironworks, kilns in which fire-bricks are burned are heated by means of part of the waste gases from the blast furnace.

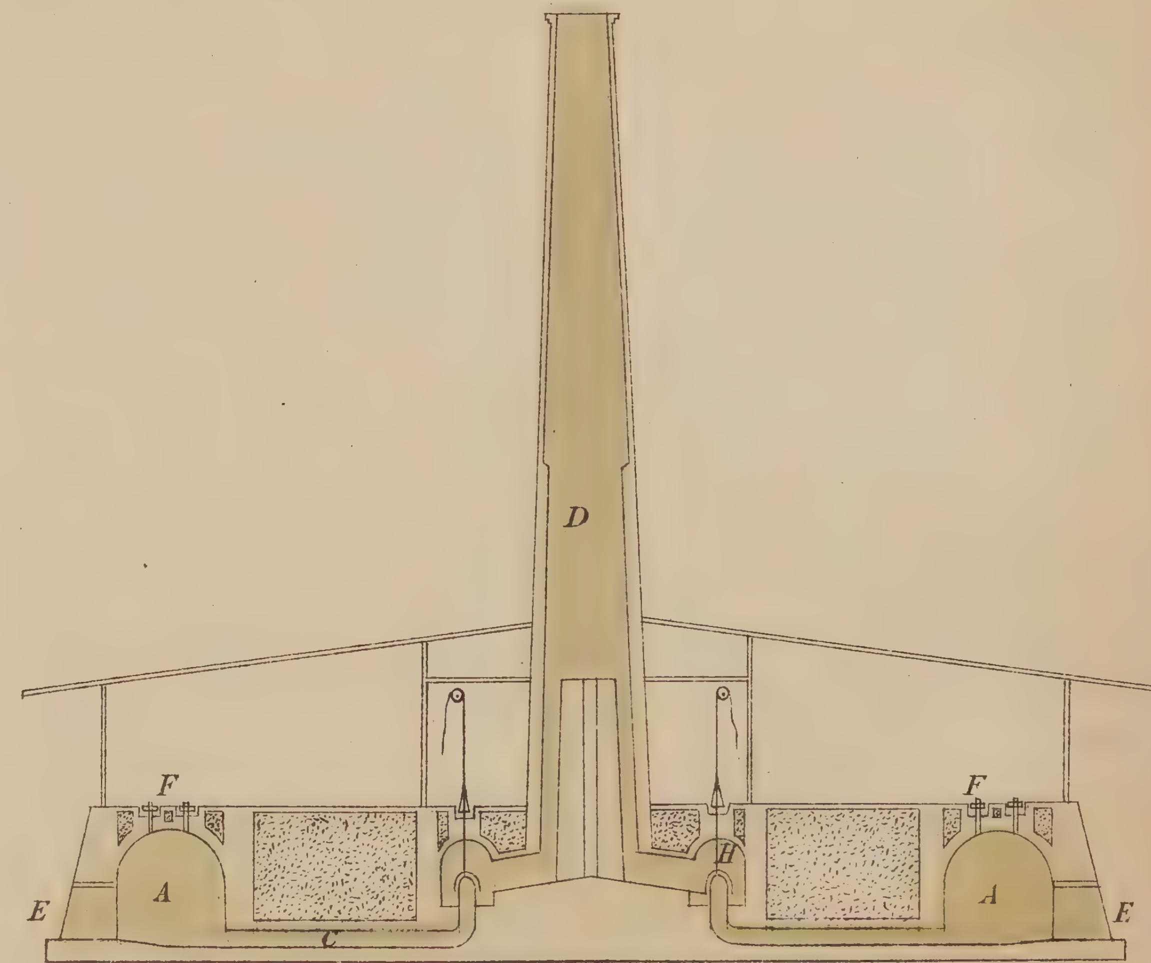
Closed kilns.

b. Closed kilns.—Under this head I include all kilns, whether circular or oblong, which, while burning, are closed in at the top, notwithstanding that there are openings at the top which are uncovered during cooling or discharge of the kiln. In such

HOFMANN'S KILN.



PLAN.

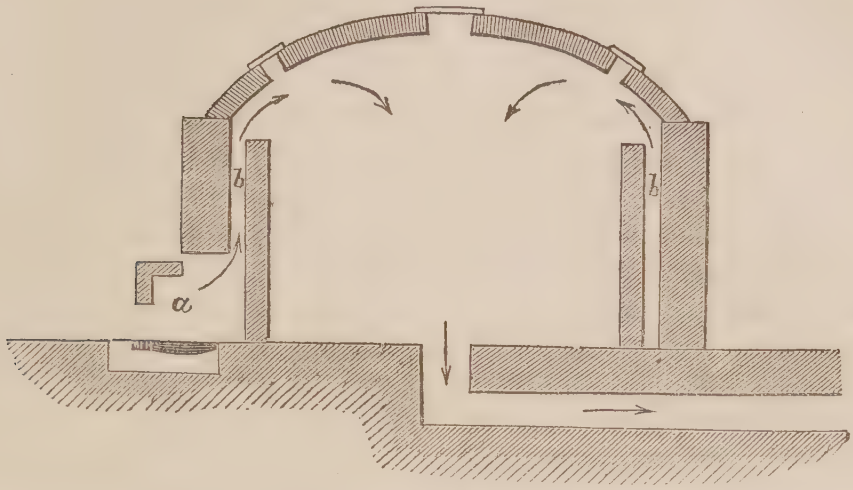


SECTIONAL ELEVATION.

DANGERFIELD.LITH.22.BEDFORD ST COVENT GARDEN.

kilns as these, represented in the rough diagram, Fig. 3., there are fireplaces *a* constructed round the kiln, as many as may be requisite, and

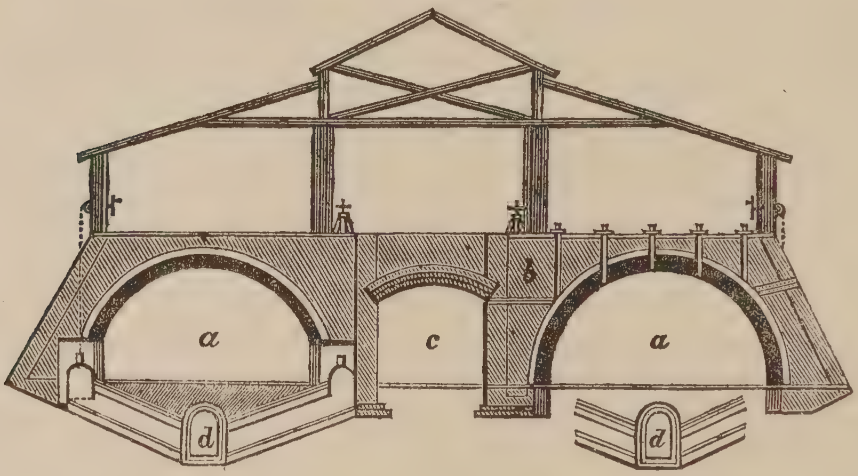
Fig. 3.



from each proceeds into the interior of the kiln a short chimney (technically "a bag"). Sometimes all the fires discharge into a fire-brick space *b* running all round the kiln, or as it were all into one continuous "bag." The flame and hot air from the fires are thus directed upwards at the sides of the kiln, and then descend from above through the charge to flues beneath the floor of the kiln, as indicated by the arrows. These flues either lead to a chimney outside or to a chimney passing up through the middle of the kiln itself. Kilns such as these are used in Staffordshire for the burning of blue-bricks. Clay such as that dug at Basford, near Stoke-on-Trent, is burned either red or blue by varying the draught through the kiln. The length of the flues and the height of the chimney are matters of importance, which will be referred to later on. As respects closed kilns also, there are modifications in details observable at different works, but they need not be dwelt on here. But there is one kind of closed kiln which requires a special description, namely, the "Ring-ofen" or Hofmann's circular kiln, which is used now at several large brick works about the kingdom. The chief object of its design appears to have been the economising of fuel, an object unquestionably attained. Plate II. represents the essential points in its construction. A number of kiln chambers (*A*) are arranged in a ring: in the centre of the ring is a chimney (*D*), and from the right hand inner lower corner of each chamber a flue (*C*) communicates with the chimney. There are moveable iron partitions (*B*) between the chambers. Each chamber has a doorway (*E*) on the outside of the ring for charging and discharging it, and a number of openings (*F*) in the top for the supply of coal from time to time. Each flue from the chambers enters into a common flue (*G*) near the centre, and at this spot is provided with a damper arrangement (*H*), worked from the top of the kiln. The kiln is worked round and round continuously thus:—Suppose on any day No. 4 chamber to be in the fullest state of ignition, its doorway (*E*) would be found bricked and plastered up closely, and the partition (*B*) would have been removed, and the flue (*C*) from it closed by the damper; No. 5 chamber would be found at a red heat, but less actively ignited, with doorway and flue also closed, and the partition (B') removed; No. 6 chamber would be found filled with green bricks, and just getting hot, the doorway closed, the flue to the chimney open, and the partition (B'') undisturbed. In No. 7 chamber the process of filling would be going on. So much for the chambers to the right of No. 4. Looking now to the left of it, No. 3 chamber would be found in the

first stage of cooling, but still probably at a low red heat, door and flue closed, and of course without the iron partition from No. 4. No. 2 chamber would be found with the door open, the flue closed, the partition B''' wanting, and the chamber probably nearly cool. No. 1 chamber would be quite cool, and undergoing first discharge of the burned bricks, and then the recharging with green bricks ; the door of course would be open, the flue closed. Up to the end of the discharging process the partition B'''' would of course be wanting, but before recharging it would be restored. The partition between chambers 12 and 1 would be *in situ* until close upon the completion of charging, when it would be removed. When the green bricks are built up within a chamber, vertical passages are left from the top to the bottom, corresponding with the feeding apertures for fuel (F) at the top of the kiln (which apertures are kept covered except during feeding), and there are horizontal channels left at the bottom of the charge corresponding with these vertical channels. The coal is introduced in a fine, almost dusty condition, a shovel full only at a time, according to the stage of the burning and the requirements of each chamber at the time. The economy of coal is said to be very great, and it depends on the fact that very little heat is wasted, the air for the combustion in No. 4 being supplied hot from having to reach it through the heated charges in Nos. 2 and 3, while the hot air from No. 4 (in full ignition) has to pass through Nos. 5 and 6, heating and igniting their charges before reaching the flue by which it is discharged. The only practical objection I have heard raised against this kiln is that the bricks which lie nearest to the circumference of the kiln are apt to be insufficiently burned, in consequence of the heat being less in this part on account of the position of the flue being on the side nearest the centre of the kiln. Lancaster's patent "continuous kiln" has been designed to obviate this defect. Fig. 4 shows the arrangement in section. It consists of a series of

Fig. 4.



chambers *a a*, constructed much on the Hofmann principle, and arranged in two parallel lines connected with each other by curved chambers at one end, so that the completed structure has the form of a horse-shoe, a passage *b* being left between the two rows. The whole structure is covered in by a roof, and the passage between the two rows of chambers is also covered. There are entrances to each chamber both from this central passage and from the outside, the chambers being charged through the former and discharged by the latter openings or doorways. But the most important point is the arrangement of the flues: there is a large central flue *d* running beneath the floor along the whole length of the series of chambers, and terminating at one end of the horse-shoe

in a chimney shaft, and from this central flue there proceed in each chamber two branch flues, one of which opens on one side and the other on the other side of the chamber, as shown in the section. The kiln is worked round chamber after chamber from one end of the horse-shoe to the other, coal slack being fed in at the top of the openings *b*. This form of kiln has as yet been only partially adopted at one establishment near Leeds.

Nuisance from brick-burning.

Brick burning is a very common cause of nuisance, burning in clamps being especially offensive. About London, in new neighbourhoods where brick-earth is dug on the spot and bricks made for use on the spot close to inhabited houses, the nuisance is notorious, and has frequently given occasion to legal proceedings being taken to bring about its suppression. The things complained of in brick burning are the continuous issue of smoke, sometimes of emanations irritating to the respiratory organs or distinctly acid and pungent, and sometimes, especially from clamp burning, of a very offensive odour of a somewhat putrid character, leading people at times to think that it is an odour arising from defective sewers or drains. The smoke is only a nuisance in the immediate vicinity of the kilns; the acid vapours may be a nuisance at a distance of 200 yards—such is said by Mr. Turner, the Medical Officer of Health for Portsmouth, to have been the case there—but the putrid odour mentioned above is apt to be a nuisance over a considerable tract of country, even to the distance of half a mile and more from the kilns from which it issues; of course it is much more offensive in their immediate neighbourhood. Where a clay of old geological formation, such as that of the colliery district of South Staffordshire, is used, and when coal is employed as the fuel, the only nuisance that arises is that which is due to the issue of smoke and sulphurous acid from the coal used. The nuisances arising from brick burning have often been alleged to be injurious to health. In one sense, and indirectly, no doubt they are so, inasmuch as when the wind brings the offensive odours in the direction of inhabited houses, the residents keep their windows and doors closed in the hope (often the vain hope) of excluding the offensive smell or smoke. More directly the utmost that it appears to me can be truly said is, that the effluvia, when concentrated, produce sometimes a sense of oppression of breathing, and even when diluted by diffusion through the atmosphere some of those disturbances of the system which in my first report I referred to as probably due to the disagreeable impression made upon the senses, such as headache, loss of appetite, sickness, nausea, or vomiting.

Sources nuisance.

Referring now to the nature of the effluvia and their sources, the smoke consists partly of watery vapour and partly of fuliginous matter from the imperfect combustion of the combustibles used in the kiln. The watery vapour is given off principallg in the earlier stages of ignition, and carries off with it the more volatile matters in the charge, such as sulphuretted hydrogen, which gas is sometimes in sufficient quantity, Dr. Bernays informs me, to blacken silver articles in the neighbourhood. The quantity and chemical nature of the smoke vary with the kind of fuel or coal used in the kiln, with the stage of the ignition, the freedom with which air is admitted, and the sort of kiln employed. The more bituminous the coal, other things being equal, the greater will be the amount of smoke, and it is greater in the earlier stages of ignition of the kiln, when the bricks are not hot, than later on in the burning when the bricks have become fully ignited, and also from time to time when the fires are replenished, especially at the early stages. The effect of a free admission of air or the reverse is noticeable in kilns where red or blue bricks are made (as in Staffordshire) from the same kind of clay.

When bricks are to be burned red, air is freely admitted into the kiln, the object being to have a sufficiently oxidising atmosphere within it to secure the peroxidation of the iron in the clay which imparts the red colour. On the other hand, when bricks are to be burned blue, the supply of air is restricted after the first 36 hours of burning by allowing clinkers to accumulate in the fore part of the fireplace, and by loosely bricking up the front of the fireplace or feeding aperture; and then much more smoke is evolved. Close kilns have appeared to me, so far as I have been able to watch their working, to evolve less smoke than open kilns similarly heated with coal. The reason probably is, that in the former case the volatile matters from the coal are, as they rise towards the top of the kiln, freely mixed with air previously heated, that time is afforded for their more complete admixture, and that, in consequence, their perfect combustion, as they pass down through the ignited charge, is more certain than when they rise directly from the fire into the charge of bricks. Very much also depends upon the construction of the close kilns and their mode of stoking. The Hofmann kiln gives issue to very little smoke, for the obvious reason mainly that the quantity of coal used is reduced to a minimum; and the same to a less degree is the case where a kiln is otherwise so constructed and stoked as to economise fuel and ensure its perfect combustion as it is supplied to the fires. As regards the emanations which irritate the organs of respiration, some are distinctly acid, both to the senses and to test paper. Judging merely by the senses, this acidity appears to be due mostly to the sulphur acids evolved in the combustion of the fuel. A crystalline matter, commonly found on the top of clamps of bricks in the later stages of burning, I found to be chloride of ammonium. It is not unlikely that a good deal of this salt sublimes during the process. Volatile empyreumatic matters of organic origin, probably in some variety, combine to give rise to the offensive odours chiefly given off in clamp burning; and so far as this element of the offensive odour is concerned, the offensiveness varies with the nature of the clay used in the making of the bricks. The clay used in the London and Kentish brickfields gives off a good deal of this particular kind of matter. But much of it is due to the organic matter mixed with the ashes and breeze used for igniting the kiln, or mixed into the substance of the bricks. No such odour is given off when the clays of older geological formation, such as those of the coal measures, are used.

Prevention of nuisance from clamp-burning;

Brick burning being commonly so offensive a process as it is when carried on near inhabited places, and being so common a source of nuisance about London and large increasing towns, the way in which the nuisance may be reduced is a question of some importance. Clamp burning is without controversy by far the most offensive mode of burning bricks, and unfortunately for the comfort of Londoners it is the traditional mode of burning bricks about the metropolis and in Kent for use in building London houses; and a tradition of this sort, affecting an important and fluctuating business like brickmaking, is a most difficult thing to overcome. Builders also have their traditions, and they demand bricks of a certain character and appearance. Now this is the cheapest method of making and burning bricks of the sort that is wanted, since they can be made and burned anywhere on the spot at which they are to be used without the expense of erecting a kiln, and the fuel employed is very much cheaper than coal, being refuse matter which it might not otherwise be easy to find another use for. It is true that clamp burning is in some respects wasteful, since, in consequence of the irregular way in which the heat may be distributed through the clamp, some of the bricks are sure to be spoiled, being either under-burned or over-burned, and fused together

into what are called "burrs." Still, after making all allowances of this kind, it is the cheapest mode of brick burning. Nothing but considerations of this kind can, as it appears to me, justify the continuance of the toleration accorded to clamp-brick burning around London. But, as the practice is tolerated and appears likely to be continued, it has to be considered in what way the nuisance can be in any degree lessened: and the only element in the process that appears to be practically open to improvement is the selection of fuel, viz., either a more careful separation of the organic matter from the ashes and breeze used than has hitherto been customary, or, still better, the entire substitution of small coke (*e.g.* gasworks breeze) and coke dust, or washed breeze from puddling furnaces, &c., for dust-bin breeze and dust-bin ashes. I confess that I think that, within the metropolitan area at least, it would be no grievous hardship to require this substitution to be made. As respects the dust-bin breeze and ashes, it is to the advantage of the brick-maker to separate obvious organic matter from them as completely as he can; otherwise his calculations as to the quantity of fuel he is using may prove to be in fault, and the result may be the spoiling of the whole clamp of bricks from defective burning.

from kiln-burning.

When bricks are burned in kilns, it is usually in some place which is permanently, or at any rate for a sufficiently protracted period of time, devoted to the manufacture of bricks. This fact brings kiln-burning into the same category with other trades having fixed localities, and enables it to be dealt with more readily with a view to public comfort and convenience than is the case commonly with clamp burning. As respects open kilns a great deal may be done to lessen the smoke nuisance by a more careful and steady method of stoking than is usually practised. Instead of heaping in coal upon the fires at long intervals, it would conduce to the lessening of smoke, and in the long run I believe to the economy of fuel, if it were fed in at shorter intervals, and in smaller quantities at a time, and if the fires were not all supplied with a quantity of fresh fuel at about the same time. Where sulphurous fumes are a nuisance, the use of a less sulphurous coal would perhaps sufficiently lessen the annoyance. But after all, the best remedy for the nuisance of kiln burning is the use of some form of closed kiln, either the Hofmann's or some other form of "continuous kiln" where heat and fuel are economised, or an ordinary closed kiln, with long flues and tall chimney shafts, such as may be seen in use at Campbell's Brick and Tile Works at Stoke-on-Trent, or at E. Brooke and Sons' at Huddersfield. At Campbell's works the long flues from closed kilns, where blue and red bricks are both made, pass under the floor of the drying shop, and after heating it communicate with a tall chimney shaft. But such tall chimney shafts as those just referred to are expensive constructions, too expensive for small makers, and the expense of its erection similarly restricts the usefulness of the Hofmann kiln to large works. One of the advantages claimed for the Lancaster "continuous kiln" is, that it is to some extent adaptable to the needs of small works, in that five or more chambers can be built and worked at a considerable saving without completing the full set, the only disadvantage arising being the necessity to recommence firing each time the last kiln is reached. There is another kind of kiln in which heat and fuel are economised which appears to be well adapted to small works. It is a modification of what I believe is termed the "Newcastle kiln." (See p. 91) It consists of a row or block of five or more close chambers, the doorways of which are placed alternately on opposite sides of the row, so that the front part of each chamber adjoins the back part of the chambers on either side of it. Within each chamber or kiln a free space of about 3 feet

is kept in the front part, the rest of the chamber being filled with green bricks to the top, where are feeding openings as in the Hofmann kiln. From the lower part of the back wall of each chamber a flue proceeds underground to the front unoccupied part of the next adjoinin chamber, where it opens upon the floor. The bricks are so arranged a to leave spaces along the floor to within 3 feet of the back wall, and vertical spaces are also left, as in the Hofmann, beneath each feeding hole. The first chamber has to be burned by fires occupying the free space in front, but all the succeeding ones are fired first by the waste heat from the adjoining chamber, and subsequently by slack fed in by the openings above. This form of kiln may be seen working at G. Lees' brickworks at Leeds, and I am informed gives satisfactory results.

Ballast Burning.

Ballast burning.

It is a very common practice about London to burn the stiff clay which is dug out for the foundation of houses, so as to convert it into a rough brick-like substance which is technically termed "ballast," and which is used for the making of new roads. Clay and small coal or "slack" are laid alternately so as to form a heap, sometimes broad, and a few feet high, at other times in the form of a circular mound, and then the heap is ignited and allowed to burn out, or the heap is continuously added to as the burning proceeds. The heap burns with the evolution of a good deal of smoke, and of a very offensive empyreumatic effluvium partly due, as in the case of brick-burning, to the destructive changes undergone by the organic matter in the clay. The nuisance that is occasioned is very similar to that of brick burning about London, and, like brick burning, has been on some occasions the cause of legal proceedings being taken to obtain its abatement. Ballast burning can scarcely be said to be a legitimate trade. It is invariably carried on in the locality where the clay is dug, although the ballast which results is not always used or required for use in that locality. The fact mostly is, that the clay has to be got rid of and that its removal in the crude condition would give rise to expense, while, when it has been burned into ballast, it can be disposed of by sale. In an economical point of view this is an important consideration when an estate of some acres is being covered with buildings. In such a case as that, the nuisance is continuous so long as new houses are being erected in succession. So far as I know, ballast is never burned in any other way than I have described, nor am I aware of any attempt having been made at any time to obviate the nuisance occasioned by the process. It is, in my opinion, a proceeding for which, when it is a nuisance to residents in the neighbourhood, there is no sufficient excuse in the small saving of cost for cartage of clay which is effected. Hence, should it at any time be held essential that the clay should be burned where the burning is likely to be a nuisance, it should be burned in such a way as to bring the effluvia under control. I see no reason why it should not, under such circumstances, be burned in a kiln with due provision against nuisance from the empyreumatic vapours and smoke emitted. If it is absolutely necessary that ballast should be burned in heaps, it appears to me that the method which was adopted by Mr. Jones (p. 105) to prevent nuisance from coking in heaps, or some similar method, would be applicable. If it is worth while to burn the clay at all, it ought also to be considered worth while tc do it inoffensively.

MANUFACTURE OF PORTLAND CEMENT.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Oct. 1875 -	Buchanan -	Southampton -	Burning lime and bricks.
„ „ -	Elliott - -	Ditto - -	Baking of plaster of Paris.
„ „ -	Hooper and Ashby	Ditto - -	Coke making. Brick burning.
Dec. 16, 1875 -	Harvey - -	Plymouth.	—
Jan. 19, 1876 -	Commercial Cement Works.	Bristol.	—
„ 11, 1877 -	Crease - -	Portsmouth -	Coke making.
Feb. 1, „ -	Browne & Co. -	Dumball.	—
May 14, „ -	Bankhall Cement Works.	Liverpool -	Burning felt sheathing of ships.
Mar. 16, 1878 -	Corporation Cement Works.	Burnley.	—
Nov. 19, „ -	Burham Cement Works.	Burham, near Maidstone.	Brick burning; lime burning; coking.
„ 22, „ -	Hilton, Anderson, & Co.	Faversham -	Coking.
„ 23, „ -	Burham Cement Works.	Murston, near Sittingbourne.	Ditto.
„ 28, „ -	White and Sons -	Greenhithe.	—
„ 29, „ -	J. C. Johnson -	Ditto.	—
„ „ „ -	Robins & Co. -	Northfleet -	Coking.
Dec. 6, „ -	Bevan - -	Ditto - -	Ditto.
„ 11, „ -	Francis & Co. -	Cliffe, near Higham.	Ditto. (Two establishments.)
„ „ „ -	Johnson & Co. -	Ditto - -	Ditto.
„ 12, „ -	E. C. Gibbons -	Shotley, near Ipswich.	Brick making.
„ 13, „ -	Patrick - -	Dovercourt -	Coking; brick making.
„ 16, „ -	Hooper and Ashby	Southampton -	(Second visit.)
May 16, 1879 -	Portland Cement Works.	Holywell, Flintshire.	—
July 2, „ -	Howden Cement Works.	Howden on Tyne.	—

Hydraulic cements.

Two kinds of hydraulic cement are manufactured in this country. They are commonly known by the names of "Roman cement" and "Portland cement." Roman cement is mostly made from the septaria nodules which occur in the London clay formation in the Isle of Sheppey and on the coast of Harwich. These stones are simply calcined in open kilns like lime-kilns. The effluvia from the burning are not very agreeable to the senses, but I have never heard of any complaint being made about them. It is otherwise with the manufacture of Portland cement, which has now so far superseded Roman cement that very little of the latter is now made.

Process of manufacture of Portland cement.

Portland cement is made from an artificial mixture of clay and chalk, or in some places of clay and limestone. The clay used is, for the most part, of comparatively recent geological formation; in rare instances the clay used is of older formation, but the manufacture, so far as my inquiry is concerned, may be taken to be from alluvial clay or mud, such as that found on the shores of some tidal rivers, and either grey or white chalk. At Burham the clay used is the blue clay from the gault formation. The clay or mud used at the various works at Northfleet and Greenhithe is obtained from the banks of the Medway;

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that used at Southampton from the river Itchen; and that used at Dovercourt and Shotley from the river Stour. All these are recent alluvial deposits; they are, when newly dug, of a blue colour and butyraceous consistence. That from the Medway is commonly more or less mixed with peaty matter (avoided indeed as much as possible in digging it), and that from the Itchen I have on some occasions found smelling offensively of sulphuretted hydrogen, and containing the *débris* of bivalve molluscs. It is only necessary further to say here that, at Burnley, Portland cement is being made from the sludge resulting from the precipitation of the sewage of the town with lime.

I have been favoured from private sources with the following results of analysis of materials used in making Portland cement in several of the manufactories that I have visited:—

Clay used at Ashby's, Southampton. (Angell.)

Moisture - - - - -	32·2
Loss on ignition - - - -	7·2*
Mineral matter - - - -	60·6
	100·0

Clay used at Francis & Co.'s works, Cliffe (dug from a field near chalk quarries). (Dr. Russell.)

Loss of water at 248° - - -	37·07 per cent.
" at dull red heat (water and organic matter) - - - -	4·24 per cent.†

Raw materials used by Burham Cement Company. (From a Paper on Portland Cement by C. Colson, Associate, Inst. C.E.)

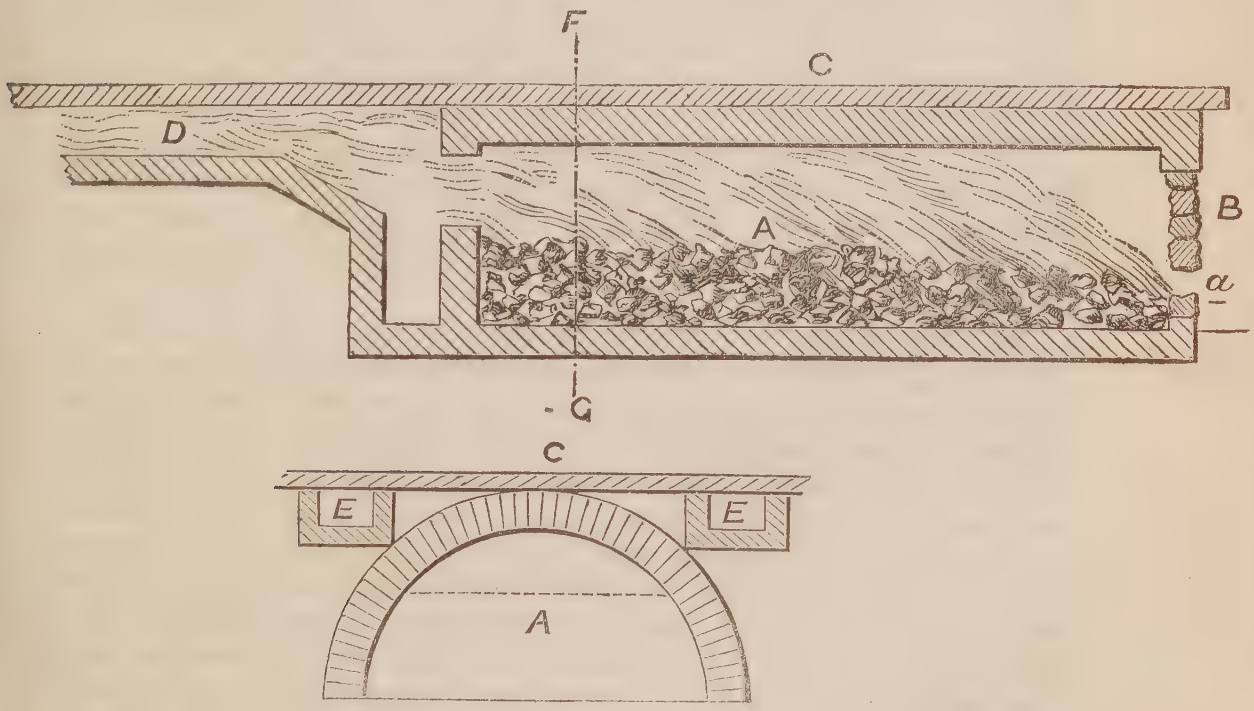
Gault Clay.		*Grey Chalk.*	
Silica - - -	46·61	Carbonate of lime -	87·50
Alumina - - -	16·06	Silica - - -	7·00
Oxide of iron - -	6·07	Alumina - - -	1·15
Carbonate of lime -	25·06	Magnesia - -	1·00
Magnesia - -	·60	Oxide of iron - -	·30
Potash - - -	·60	Organic matter and water	3·05
Water and organic matter	5·00		
	100·00		100·00

The proportions of chalk and clay used vary with the composition of each, and the results obtained by testing the cement daily. Grey chalk requires considerably less clay than white chalk. At the Burham Works one part of clay is used with four or five parts of chalk, but usually when grey chalk and river mud (such as Medway mud) are used, the quantity of clay added is rather more than this. When white chalk is used it is common to add one part of river mud to two parts of chalk. These materials are usually thrown into a circular brick tank, or shallow pit, into which water is run in excess, and where they are broken down and washed by a mechanical arrangement which need not be described. The water holding the washed materials in suspension, sometimes after passing through a succession of such mixers, is run off into a pit where gritty or insufficiently disintegrated material may become deposited, and thence is run off or pumped up in a creamy consistence into large "backs," or shallow reservoirs, where the mixture

* Containing nitrogen 0·238 per cent.
† Containing nitrogen 0·076. (Probably in clay as ammonia.)

is left to deposit the suspended material. There are always several such backs, which are used in succession. When the deposition is complete, the supernatant water is run off: and the sludge left behind, then known under the technical term "slurry," is in a condition to be dug out. Some manufacturers, such as White and Johnson, economise space and water and shorten their process considerably by using what is known in the trade as the Goreham process. No more water is put into the mixer than shall suffice to make the chalk and clay used into a sludge just thin enough to flow through the channels provided for its conveyance; the sludge is subsequently ground down to an uniform smooth consistence in an appropriate milling apparatus, after which it is simply run off on to the drying floors. So far as my Report is concerned with this process, I have only to observe that the soluble salts which would be washed out of the clay and chalk in the old process are retained in the "slurry" made by the Goreham process. The "slurry" being thus made, it is dug out from the "backs" and carried in wheelbarrows, or, in the case of the Goreham process, run off by appropriate conduits to the drying floor (within a chamber or open shed) to be dried. For the most part these drying-floors are simply floors paved with plates of iron, or fire-bricks, or fire-clay tiles, and heated below by flues proceeding from coke-ovens constructed in a row along one or both opposite sides of the drying-floor. From these ovens flues proceed beneath the floor, and terminate in one or more chimneys, usually low chimneys. It will be convenient to defer any description of these ovens until the subject of "coking" arises in a later part of this Report, (p. 99) but the following rough plan, Fig. 5., indicates the customary arrangement of the

Fig. 5.



ovens and flues. At some works coke fires are used to heat the flues, as at Ashby's, and at other works ordinary coal fires. On these drying-floors the slurry remains until it is dry and hard, and as it becomes dry it cracks across into irregular masses; the lower surface often becomes somewhat burned by the heat of the floor. It is now in a condition to be transferred to the kiln. The kiln used is sometimes different in no respect from an ordinary egg-shaped lime-kiln, being quite open at the top and lined with fire-brick; but for the most part, although this shape is more or less followed, the kiln is covered in with a conical or

"beehive" brick top, or in some other way, the top part of the conical head being left open. The precise shape of the kiln differs at different works, but where open kilns are used the construction is in other respects very similar. At the level of the top of the kiln proper there is an opening or "eye" for introducing the charge, and where the kiln is large there is another "eye" for the same purpose about 8 feet lower down, and of course there are platforms outside corresponding with the openings. The bottom of the kiln is closed by movable fire-bars, beneath which is a space into which the charge falls on removal of the bars when the burning is finished. The size of the kiln also varies, some kilns being constructed to burn as small a charge as seven tons, and others (at the more extensive manufactories) to burn as much as 30 or 35 tons at a charge. For the most part each kiln is constructed to burn about 22 or 25 tons. In charging a kiln, faggots are first placed on the bars at the bottom, and on these a layer of coke (either made on the premises or purchased from gasworks), and then alternate layers of dried slurry and coke until the kiln is full to the top. The faggots are then lit and the eyes bricked and plastered up, or covered with an iron plate luted round the edges with clay; and in time the kiln burns through. According to the size of the kiln and the charge it holds and the amount of draught obtainable, the cement is fully burned and ready for drawing in from three to five days. Some manufacturers tell me that they find it convenient to have the kiln of such a size that two charges per week can be burned. I am informed by some of the principal manufacturers that, so long as uniformity of burning is obtained, the charge cannot be burned off too speedily. At some works, when the charge being burned down has sunk a little in the kiln, it is filled up again to the top with slurry, a process termed "topping-up," and then the kiln is allowed to burn out. In other works the kiln never goes out, but, as finished cement is drawn out from time to time at the bottom, fresh material and coke are thrown in at the top, the process being thus rendered continuous.

What I have been just describing is the old customary mode of burning cement, which may be seen in operation at many of the cement works in the kingdom. I shall defer the description of other modes of burning, in which closed kilns or kilns which are virtually closed are used, until later in this article.

Nuisance occasioned.

Cement-making thus pursued, or pursued even with what have been regarded as closed kilns, but allowing of the escape into the air of the volatile products of the operation, has on several occasions been the subject of grave complaints of nuisance. From time to time legal proceedings have, during the last few years, been instituted against one manufacturer after another, with the result that several of them who operate on a considerable scale are now working under injunctions. Ordinarily there proceed from such works considerable volumes of smoke and vapour, sufficient in amount to cloud the air and obstruct the view of neighbouring parts, the smoke and vapours passing from the works at a low level and sweeping as a cloud over a considerable tract of country. The smell of these effluvia is partly that of ordinary coal smoke, but what has mainly been complained of is a more or less strong offensive odour, which has been compared to that arising from clamp brick burning about London. On numerous occasions I have exposed myself to these vapours, and can say that in the main this comparison is correct. But I must add that the offensiveness of the odour as proceeding from different works varies very greatly, not only in its intensity, but also somewhat in its character. It has appeared to me, visiting works as I did at varying intervals, and carrying with me only the memory of the

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odours, that the intensity of the offensiveness varied from almost nothing, where clays of old geological formation were used, to something very disagreeable indeed where the more recent deposits were employed. The odour which was most offensive to me was that proceeding from works in which the clay from the bed of the river Itchen was used, probably on account of the quantity or quality of its organic constituents. The odour partook not only of a brick-burning character, but of the smell that proceeds from burning animal matter, such as bones.

Effect upon health.

There is a good deal of uniformity noticeable in the statements that have been made on various occasions with respect to the effect of cement fumes upon the health of persons whom they have reached outside works. Headache, loss of appetite, a disagreeable taste in the mouth taking away the relish for food, a parched sensation in the mouth and throat, nausea, and vomiting, with sometimes oppression of breathing, are the effects commonly attributed to full exposure to the fumes for some time; and although I have not myself been unfortunate enough to suffer in any of these ways on exposure, and although I can scarcely refrain from believing that exaggerated statements have not rarely been made as to the evil effects of these fumes upon health, I have reason to believe that such effects have been more or less experienced on some occasions by various persons. Dr. Thorne, who some years ago visited the works at Cliffe on complaint made by the authorities at the War Office, stated, in a report which he made to the Board in 1873, that the fumes proceeding from these works were, to his senses, highly disagreeable, leaving an acidulous taste and a slightly parched feeling in the mouth for some time. He added that " the general testimony of persons " residing in the huts near the fort (some 50 to 100 yards from the " works, which huts have been since demolished) was, that when the " fumes were blown towards them from the works, they were at times " 'nearly suffocated,' that they suffered from headache, and that the dis- " agreeable taste left in their mouths by the fumes prevented the enjoy- " ment of their meals; and that, in some instances, their children's rest " at night had been interfered with." One woman, who was labouring under an affection of the chest associated with difficulty of breathing, stated to Dr. Thorne that the fumes caused her great distress, and induced a choking sensation accompanied by copious expectoration, and unfitted her for her duties for the day. Some of the effects complained of are probably only due to the effect of the disagreeable impression made by the fumes upon the senses, but others, such as the dryness of the mouth and throat and the oppression of breathing, &c., must be held to be probably due to the direct operation of the fumes upon the respiratory tract.

Mr. Osborn, the Medical Officer of Health for Southampton, replying to a letter from me on July 30, 1875, at a time when a cement-making nuisance at Southampton had been brought under the notice of the Board by the Corporation of that town, says, " Some persons who are " directly exposed to the fumes complain of headache, nausea, and a " sense of constriction of the chest and dryness of the mouth and lips," adding, " I have often, though not recently, experienced these effects on myself by contact with the fumes . . . . Persons residing " at least a mile from the works complain quite as much, or rather " more, of the nuisance than those residing in close proximity, and " when the fumes penetrate into dwelling-houses or churches the nui- " sance is said to be very great, and several persons have been com- " pelled to close their windows in hot weather to exclude the fumes."

I may add that an experienced medical man, whose statements I can rely upon implicitly, and whose practice is extensive enough to include

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Northfleet, where some of the largest cement manufactories in the kingdom are situated, and where the atmosphere is commonly charged with the emanations from the works, informs me that he has known the place for the last 35 years, and has, since the establishment and extension of the works there, noticed a marked deterioration in the general health and aspect of the population. The people do not, he tells me, as was formerly the case, bear the robust appearance of country labourers, but are generally pale and pasty-faced, and diseases have altered to a lower type than was customary when he first knew the place. He mentioned to me individual instances of such deterioration of general health in persons exposed habitually to the fumes outside the works, and added that the depression of health which he has observed is greater in extent than would be accounted for by the other conditions which have been associated with the increase of the population in the place.

Sources of nuisance.

The several sources from which nuisance may originate at cement works may be thus enumerated:—

1. The drying of slurry on the drying floors. A good deal of watery vapour arises, of course, from the drying slurry: it has a faint odour, but, although I have often tested it with lead paper, I have never found any indication of the presence of sulphuretted hydrogen. The odour is rather stronger when the under surface of the dried slurry begins to burn. The odour is not usually perceptible outside the works, but in damp weather, when the vapour disperses less readily, it may add a little to the other odours which are perceptible outside.

2. The process of coking is one source of nuisance. It gives rise to a good deal of black smoke, which is commonly discharged from low chimneys. In addition sulphuretted hydrogen, in an amount sufficient to be disagreeable in the immediate neighbourhood of the works, is emitted when the coke is quenched with water injected into the ovens, or thrown upon the ignited coke after it has been drawn.

3. But the chief nuisance, that which is generally meant when the nuisance of cement works is mentioned, proceeds from the process of burning in the kilns. During the first few hours after a kiln is lit up, the principal thing that escapes is watery vapour, and it has little or no odour, certainly none that can possibly create nuisance. But, as the charge becomes dry and ignition proceeds, other vapours which are decidedly offensive escape, and continue to be emitted until the charge is quite burned through, and the calcination approaches completion. The offensive smell is most marked at the time when the charge approaches its greatest heat. Towards the end of the process the vapours emitted lose their offensiveness. The offensive vapour which escapes from the kilns, after the watery vapour that first comes off, is white, and deposits a white crystalline matter about the opening at which it issues, and round about any cracks there may be in the conical top, or wherever it may leak out from imperfect luting round about the edges of the charging "eye." When the vapour has been offensive at periods varying from 24 to 36 hours after the lighting of a moderate sized kiln, and later still when the kiln has been very large, I have perceived distinctly the characteristic suffocating odour of sulphurous acid; and, although I could not distinguish it by its odour, I have found the vapour to contain sulphuretted hydrogen by testing it with lead paper. The following is the result of analyses of the emanations from an open kiln of Messrs. White & Co., at Greenhithe, made in 1877, by Dr. Russell, F.R.S., Professor of Chemistry at St. Bartholomew's Hospital, and Mr. Fleming, Professor of Chemistry at Chel-

Composition of the fumes.

tenham College, at a time when these works were the subject of legal proceedings :—

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1.	2.	3.
1st Stage.—Combustion commencing. Gases rank. Plenty of white smoke. Temperature not very high.	2nd Stage.—About half-way to greatest heat. Gases very rank and strong smelling. On sucking out gases, water and tarry matter passed over. The water not acid at this period, most smell.	3rd Stage.—Full red heat. Not much smell or moisture. White dust in tube.
Oxygen - - - 17·03	11·70	2·35
Carbonic acid - - 3·89	4·27	20·56
Carbonic oxide - - 1·34	6·27	8·59
Nitrogen - - - 77·74	77·76	68·50
100·00	100·00	100·00

In addition to these gases and watery vapour, various dusty matters are thrown off as mechanical impurities; they consist mainly of sooty matter, cement dust, and volatilised salts from the clay. Dr. Russell and Mr. Fleming found the white smoke to contain silica, alumina, calcium, potasium, and sodium; the last two as chlorides derived from the sea-water which had impregnated the clay.

I collected some of the white saline deposit which had accumulated about the charging eyes of one of the kilns in Mr. Bevan's works. The following is the result of an analysis of it made for me by my son, Mr. E. G. Ballard, Associate, Royal School of Mines :—

Sulphate of lime - - - - -	16·7
„ potash - - - -	15·8
Chloride of potassium - - - -	1·4
„ sodium - - - -	2·0
Loss on ignition - - - - -	12·9
Ignited residue insoluble in water - -	51·2
	100·0

A similar saline efflorescence scraped from the interior of the flue chambers at Mr. Johnson's works at Greenhithe (which chambers will be described later on in this article) was also analysed by him with a very similar result. It gave—

Sulphate of lime - - - - -	16·3
„ potash - - - -	18·0
„ soda - - - - -	2·3
Chloride of sodium - - - -	2·4
Loss on ignition - - - - -	10·0
Ignited residue insoluble in water - -	51·0
	100·0

It is probable that the sulphates in these deposits were due to the mutual reaction of the sulphurous acid, watery vapour, and volatilised chlorides, as in Hargreave's new process for salt-cake making, described in the article on alkali manufacture (p. 199). Dr. Russell, examining the air within a radius of 280 yards around the works of Messrs. Francis & Co., at Cliffe, did not find that the carbonic acid it contained was

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appreciably in excess of that ordinarily present in atmosphoric air, and it was actually less in quantity than the average given by Dr. Angus Smith for the air of London. Mr. Fleming, experimenting on the air about Messrs. White's works, found the carbonic acid slightly in excess on one occasion near the boundary of the works, but could not in any one of 12 observations discover any excess at a distance of 200 yards from the works.

Results of Dr. Dupré's experiments.

I have now to refer to some curious results of experiments made for the Board, at my request, by Dr. Dupré, F.R.S., on the fume proceeding from Messrs. Hooper and Ashby's works at Southampton, in 1875. The occasion of the investigation was the observation of a remarkable blue colouration of gravel stones along a footpath and roadway, over the surface of which the fumes from Messrs. Hooper and Ashby's kilns were frequently swept by certain winds. Similar colouration of gravel stones has been noticed both by myself and others in the neighbourhood of gasworks, and there are some gasworks at no great distance from the cement works in question, but the precise circumstances of the gravel stones in this instance did not tally with an explanation based upon this fact. Mr. Osborn, the Medical Officer of Health for Southampton, first drew my attention to this colouration, and suggested that some cyanogen compound might be given off in the cement fume. Dr. Dupré made two reports upon this subject. It is not necessary to reproduce them here *in extenso;* a summary of them, with extracts, may suffice. In his first or "preliminary" report he stated: 1st. That on examination of the gravel stones in question he found that the colouration was due to a cyanide of iron. 2nd. That he could produce a similar colouration in similar gravel stones by exposing them to the joint action of the vapour of hydrocyanic acid, and some other strong volatile acid, such as hydrochloric. 3rd. That two samples of dried slurry, such as was burned by Messrs. Hooper and Ashby, contained respectively 4·51 and 3·36 per cent. of organic matter, and 0·09 and 0·12 per cent. of nitrogen; and hence that the production of hydrocyanic acid during the burning of it was within the bounds of possibility. 4th. That in a laboratory experiment he detected cyanogen without difficulty among the products of combustion of the dried slurry, and a small quantity of sulphurous acid. Dr. Dupré's second report was based upon investigations conducted at Messrs. Hooper and Ashby's kilns. These are close kilns, such as will be presently described, and the first observations recorded in the report were made upon the gases, &c., sucked out from the interior of the kiln by a tube passed into it at the top. The gases, &c., were made to pass through a series of glass vessels, containing, 1st, some gravel similar to that on which the blue colouration had been observed; 2nd, some pure distilled water; and 3rd, a dilute solution of sulphide of ammonium. The liquids in the second and third vessels were renewed from time to time. Dr. Dupré, in his Report, states as follows:—"After the lapse of four hours, during which time "about 80 cubic feet of the gases, &c., had passed through each of "the series of vessels, the distilled water in vessel 2 was replaced by "a dilute solution of caustic potassa, and the experiment continued "for half an hour longer. On subsequent examination, this potash "solution showed nothing which the aqueous solution had not already "indicated. The various solutions obtained were then reserved for "careful examination in London. Several tubes were also filled with "the gases for subsequent analysis. The gases and vapours drawn "thus directly from the kiln were found to be (omitting the aqueous "vapour) carbonic acid, carbonic oxide, oxygen and nitrogen, together with strong traces of sulphuretted hydrogen and ammonia,

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" and minute traces of hydrocyanic acid, or more probably a cyanide " of ammonium or sodium, a sulphocyanide, and various not definable " empyreumatic compounds, very offensive to the smell, and, lastly, an " appreciable amount of chloride of sodium, and some sulphate. The " gravel in vessel 1 assumed what at first appeared to be a blue " colouration. Gradually, however, the colour became darker, or " almost black, and proved to be due to the production of sulphide of " iron. On exposure to the air the black colour disappeared, the " sulphide becoming oxidised, but no blue colouration made its appear- " ance even after prolonged exposure. Subsequent exposure of the gravel " to the vapour of hydrochloric acid brought out, however, slight " traces of blue colour, proving that some cyanogen compound had been " formed which on exposure to the action of the acid turned blue. " The water in vessel 2 assumed a yellowish colour, and a small " amount of a black greasy-looking substance was deposited against the " sides of the vessel. The water smelt highly offensive, was neutral to " test paper, and contained a little sulphuretted hydrogen. On evapora- " tion it was found to contain 15·24 grains of solids, consisting of 14·23 " grains of mineral salts, chiefly chloride of sodium, with traces of " sulphate and sulphide, and 1·01 grains of volatile or organic sub- " stances, containing traces of sulphocyanide and cyanide of ammonium " or sodium. The sulphide of ammonium solution was found to contain " about 2·3 grains of sulphocyanic acid, the greater part of which " must have been present in the original gas in the form of hydrocyanic " acid, or more probably in that of a cyanide. The gas collected in the " corresponding tube was found to contain in 100 volumes—

" Carbonic acid - - - -	26·43 vol.
" ,, oxide - - - -	5·33 ,,
" Oxygen - - - -	1·00 ,,
" Nitrogen - - - -	67·24 ,,
	" 100·00

" with traces of all the substances mentioned above." The inferences drawn by Dr. Dupré are, " that the gases and vapours evolved during the " burning of the cement are not only highly offensive to the senses, but " contain a variety of more or less noxious and poisonous gases in " appreciable proportion. These gases, when escaping into the air, " contain all the necessary constituents for producing, under favourable " conditions, the blue colouration mentioned in my preliminary report " as having been noticed on some of the gravel stones in the neighbour- " hood of the works. The common salt carried over with the gases in " an extremely fine state of division adds to the irritating nature of the " former." I must, however, add that it does not at all follow from this investigation that all cement works give out a similar amount of cyanogen compounds, the mud or clay used on the Itchen being probably loaded with organic matter of animal origin to an unusual extent.

Prevention of nuisance.

The legal proceedings instituted from time to time against cement manufacturers, and the injunctions obtained against them, have had the excellent effect of so far stimulating ingenuity that I have no hesitation in affirming that now, with due precautions, Portland cement-making may be carried on without giving occasion to any reasonable complaints on the part of the outside public. I proceed therefore to point out the means which have been adopted by different manufacturers to prevent nuisance. I shall not confine myself to those which have been most successful, since failure is often as instructive as success. The methods

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have been, in principle, three, viz., washing the fume with water passing it through fire, and discharging it, after passing along flue specially arranged, from the top of a tall chimney-stack. I will conside them in order.

1. Washing the fume.

1. *Washing the fume.*—I am not aware of this plan having been anywhere adopted except as supplementary to another method of dealing with the fume. In 1862 Dr. Medlock and Mr. Sturge (a cement manufacturer) stated before the Select Committee of the House of Lords on Lord Derby's Bill, that after passing the fumes over a coke fire they conducted them into a cistern of 20 to 30 cubic feet capacity, containing from 3 to 4 feet depth of coke, kept wet by a watering pot, and that this sufficed to absorb all the sulphurous acid formed in the combustion of the fume. To my mind, the description given of this arrangement is that of a plaything. Again, in 1874, Messrs. Rowe and Johnson patented a washer, apparently different in no essential respect from that which I have already described and figured as in use at Messrs. Gibbs' Manure Works (*see* my first Report, p. 270). Washers on this principle were put up at Mr. Johnson's works at Greenhithe, and the fume passing from his flue chambers had to pass through one of these before escaping by a low chimney into the outer atmosphere. Mr. Johnson tells me that in this way he succeeded in arresting some of the products of combustion which escaped deposition in his flue chambers, and among other things the sulphurous acid, or some of it. But notwithstanding the washer, the nuisance from the low chimneys was such, that on legal proceedings being taken, an injunction was obtained. The washers then must be believed not to have been very successful.

2. Burning the fume.

2. *Burning the fume.*—Dr. Medlock and Mr. Sturge, in their evidence before the Select Committee of the House of Lords, spoke very favourably of the results they obtained by passing the vapours duly mixed with air over coke fires; but my observations in places where burning has been attempted, and the experience of manufacturers who have adopted the proceeding, are less favourable. I will mention some instances in point. At the very time when the offensiveness of Messrs. Hooper and Ashby's cement fume was creating such an outcry in Southampton that the Corporation of that town felt themselves compelled to take legal proceedings for the suppression of the nuisance, an elaborate arrangement for burning the fume was in operation at their works. At that time the firm had two establishments not far distant from each other. At the one, the fumes from some small cement kilns were passed into another kiln where bricks and lime were in progress of being burned. At the other, there was a series of large closed kilns (the kilns where Dr. Dupré made his experiments), from the top of each of which a flue of due dimensions conducted the fume to a series of coke fires, ending in flues that passed beneath the slurry drying floor to three chimneys, one about 100 feet high, and the other two only about 60 feet high from the ground. The flues from the kiln communicated with these fires through the roofs of the fire-places near the feeding doors. When Dr. Dupré made his investigation, detailed above, into the gases proceeding from the kiln, he also examined those proceeding from the flues after such combustion of the fume as the fires effected. The gases were drawn from a flue conveying the products of combustion, &c. from the coke fires into a main shaft, and vessels were used to collect the products similar to those he used to collect the products of combustion in the case of the kiln, and similarly charged. He thus describes the results of his investigation: "The gases, &c., after their passage through the drying "furnaces, were found to be (omitting as before the aqueous vapour)

"carbonic acid, carbonic oxide, oxygen and nitrogen, with traces of "sulphuric acid, sulphurous acid, hydrochloric acid, and excessively "minute traces of hydrocyanic acid, together with a small amount of "sulphate of sodium, and some not definable but inoffensive organic com-"pounds. The gravel in vessel 1 remained apparently entirely unaffected, "nor did it alter on subsequent exposure to the air. However, like the "gravel in the first case, it showed traces of blue colouration after ex-"posure to the vapour of hydrochloric acid, and some cyanogen com-"pound must therefore have been formed. The aqueous solution had "but a slight and not at all offensive smell; it was perfectly clear and "colourless. It contained some hydrochloric acid (0·29 grains), and "traces of sulphuric acid and sulphurous acid, and on evaporation left "1·82 grains of solid residue, consisting of 1·61 grains of fixed salts, "chiefly sulphate of sodium, with no trace of chloride, and 0·21 grains "of volatile matter. The sulphide of ammonium solution contained "extremely minute traces of sulphocyanide. The gas collected in "the tube was found to contain in 100 volumes—

"Carbonic acid - - - -	5·80 vol.
" " oxide - - - -	0·21 "
"Oxygen - - - - -	14·51 "
"Nitrogen - - - - -	79·48 "

"with traces of hydrochloric and sulphurous acids, and excessively "minute traces of hydrocyanic acid." The conclusion he drew from this examination is stated as follows: "The gases, after having passed "over the fires of the drying furnaces, have lost almost completely "their offensive and noxious character, and may, in my opinion, be "safely allowed to escape into the atmosphere." These observations by Dr. Dupré establish the possibility of so altering the chemical character of the fume by a combustion process carefully conducted, as to destroy its noxious or offensive character, since evidently on the day when Dr. Dupré made his experiments the fume in the flue on which he experimented had become thus altered. The possibility of abating the nuisance by the appliances provided at these works was established; but the desirableness of relying upon such appliances in such rough work as cement making, and with such rough men as are customarily employed in the manufacture, is quite another question, the answer to which is rendered doubtful by the fact previously stated, that nuisance really did arise from the works at a time when these appliances were believed to be in constant use. I cannot pretend to explain this fact otherwise than by saying that when, at a later date, I visited these works, offensive fume was issuing from the flues and fires, in consequence of such dilapidations in the brickwork as are inevitable under the circumstances, and that the fume in one of the flues which was opened for my inspection was certainly offensive, although much less offensive than before passing over the fires. At the works of Messrs. Elliott, also at Southampton, where materials similar to those used by Messrs. Hooper and Ashby are in use, combustion of the offensive fume is attempted in a different manner. It is not easy to explain Messrs. Elliott's arrangement without a drawing; but it may be stated that the ovens in which plaster of Paris is baked are surrounded by a flue proceeding from the cement kiln, and that the flame of the fire which heats the oven is made to enter this flue, together with an excess of atmospheric air, by which means whatever is combustible in the fume is made to be burned. To some extent (I am not prepared to say to what extent) this arrangement is successful, but the kiln is small. The principle of admitting plenty of air and giving time and plenty of space for admixture with the fume appears good, but I doubt whether Messrs.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

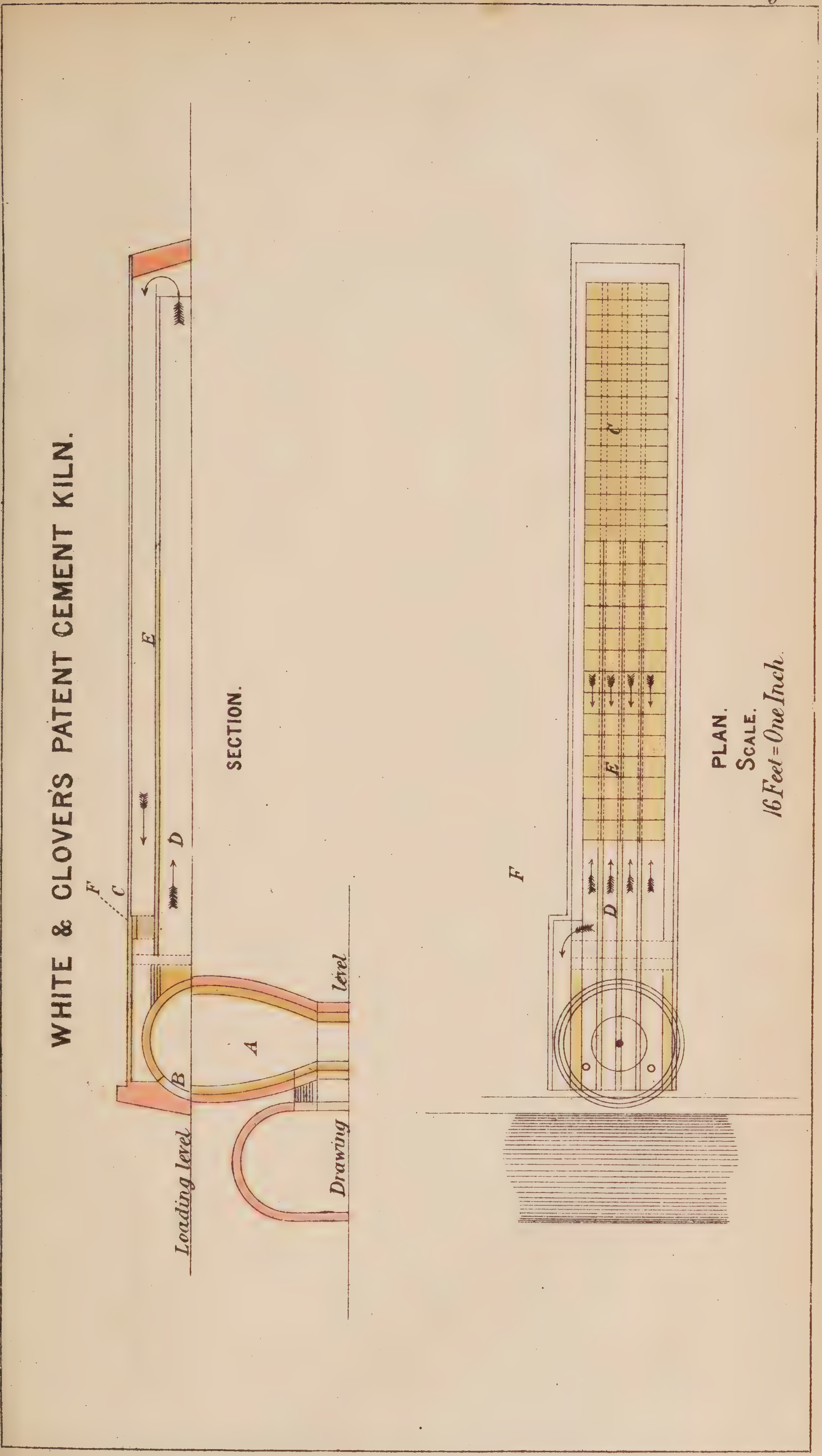
Elliott's method is applicable to very large works. Mr. De Michele, a managing partner of Francis & Co.'s works at Cliffe, when legal proceedings were taken against his firm and an injunction issued, attempted, without success, to abate the nuisance by closing the kilns and by conducting the fume into the top of the coke ovens.

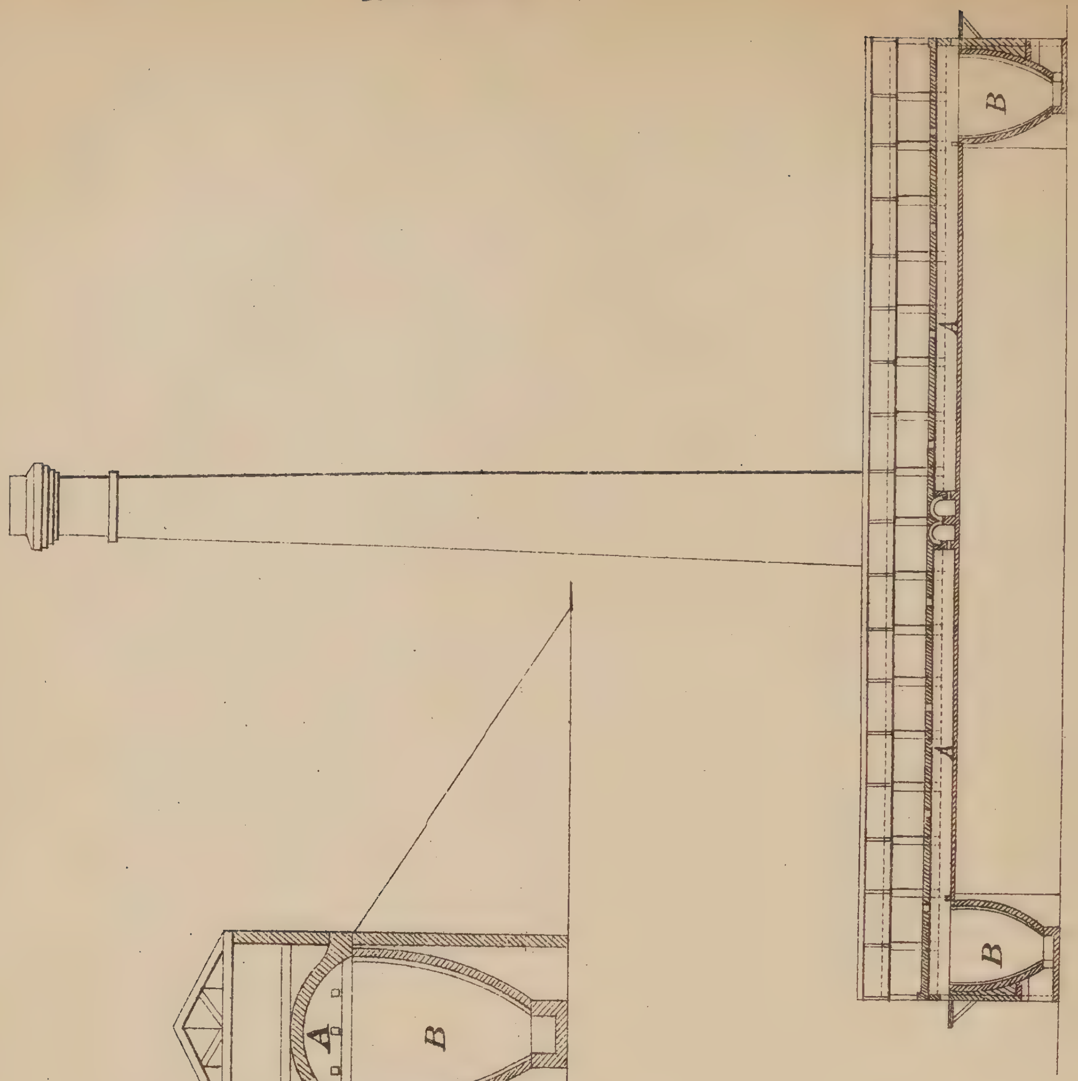
I have said that I am not favourably impressed with the success that has attended the various attempts hitherto made, so far as my experience goes, practically to abate the cement nuisance by burning the fume. I wish, however, to add that I should be sorry if this impression of mine should be held as a discouragement to further attempts in the same direction. The principle of combustion is evidently, from Dr. Dupré's observations, correct enough; the difficulty in applying it in detail practically and on a large scale is what has to be overcome.

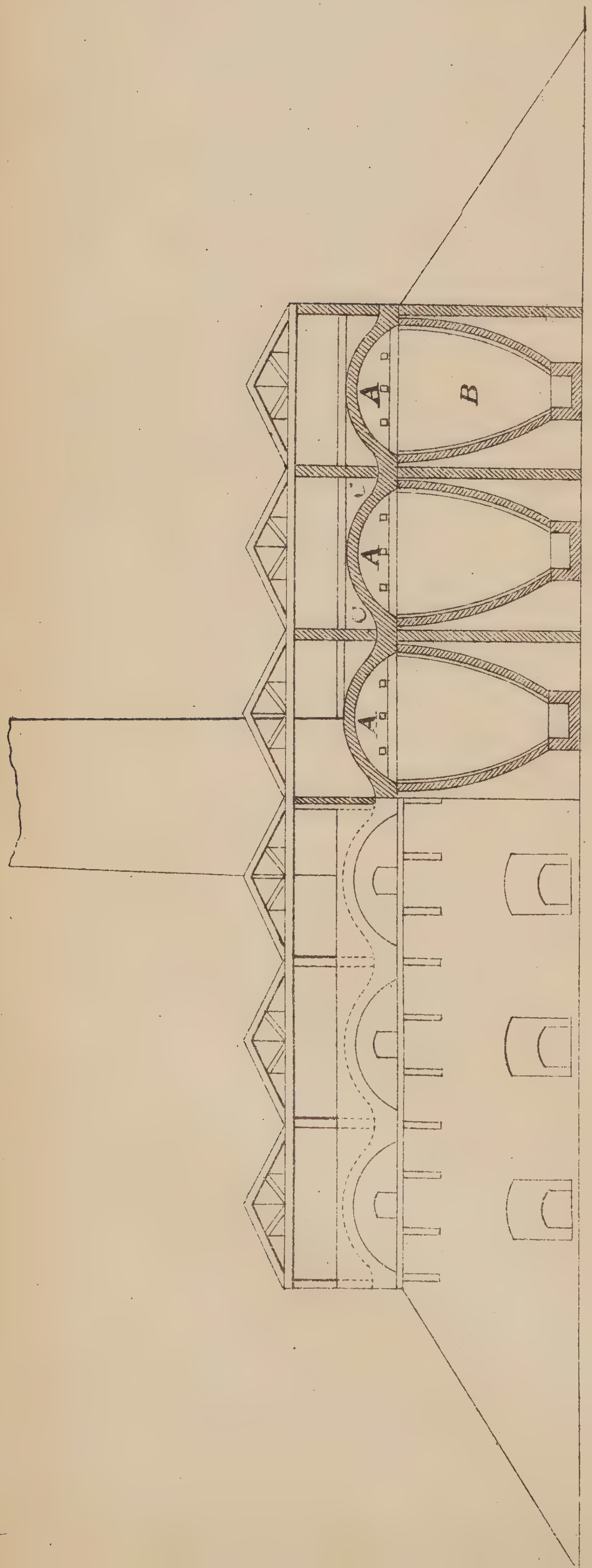
3. Use of flues and tall chimney.

3. *The use of duly arranged flues and of a tall chimney.*—Under this head I have to describe the arrangements adopted at certain works in Kent and Essex: some of these have been patented, while others have not.

1st. Messrs. White and Co.'s works at Greenhithe. When Mr. G. F. White gave evidence before the Noxious Vapours Commission in March 1877, he stated that he had adopted the Hofmann kiln (*see* Brick-burning, p. 55) for burning his cement, and that he was so far satisfied with it that it economised fuel and obviated nuisance; and it appeared from Dr. Odling's evidence that he also anticipated advantage from its introduction. Since that evidence was given, however, Mr. White tells me that his experience has gone against it, since he found he could not make with it cement of a quality that was satisfactory to him. When I visited his works last year I found that the several compartments had been converted into distinct kilns, and that he had constructed from each compartment a flue for the drying of slurry on the principle of the patent arrangement I am now about to describe. The principle of the arrangement (more fully described and figured in the Specification of Patent 1878, No. 1,347), is shown in Plate III. *A* is the kiln worked periodically. It is small, burning only about 12½ tons of cement at a charge. *B* is the charging eye, closed up when the kiln has been charged. The kiln has a domed cover having openings in it for the discharge of fume into a space beneath the drying floor *C*. From this space a flue, *D*, the width of the kiln, passes horizontally to a sufficient distance, and in it is a horizontal partition *E* made of moveable portions, so arranged that the fumes passing along the lower division of the flue may turn over at the farther end, and return, as shown by the arrows, above the partition to the end nearest the kiln, where they escape by an opening *F*, provided for the purpose, into the main flue leading to a tall chimney shaft. The roof *C* of the flue is made of moveable plates. Slurry, prepared by the Goreham process, is pumped into the flue, also on to the top of the horizontal partition, and also on to the roof of the flue which is equivalent to the ordinary drying floor. The heat from the kiln suffices to dry all three layers of slurry, and the size of these drying flues and surfaces is so apportioned to the capacity of the kilns that each kiln, in burning off, dries in and upon the flue connected with it the quantity of slurry that shall suffice for the next charge. Fig. 2 in the plate shows a division of the flues by vertical tiles each into four, but this is not essential. The advantages claimed for this arrangement are: 1. That the necessity of separate fires or coke ovens to dry the slurry is obviated: certainly a very important matter in respect of the prevention of nuisance from cement works. 2. That each kiln, drying its own next charge at the charging level of the kiln, can be recharged with that slurry immediately, while


WHITE & CLOVER'S PATENT CEMENT KILN.
SECTION.
Loading level
Drawing level
A
B
C
D
E
F
PLAN.
SCALE.
16 Feet = One Inch.
Dangerfield Lith. 22 Bedford St. Covent Garden.





JOHNSON - DE MICHELE CEMENT KILN.

the kiln is hot, and (the kiln not being more than about 11 feet deep) from the eye at the top, instead of waiting for the kiln to cool sufficiently for workmen to enter it. Since the flue dries exactly the amount of slurry for the next charge, there is no occasion to open it to remove dried slurry at any time that the associated kiln is burning, so to create nuisance. With regard to the obviating of nuisance the arrangement, so far as I could observe, is satisfactory. Such fume as is not arrested by deposition within the flues is discharged at a height of about 150 feet, a sufficient height to free the neighbourhood from the nuisance of the fumes under ordinary conditions of weather. This is not the only establishment at which the heat from the kilns is utilised by being conducted through flues to heat the drying floors. In a less elaborate manner it is done at other works, as for instance at Robins and Co.'s works at Northfleet. But the arrangement is less successful in obviating nuisance, partly because of its adaptation to some old beehive kilns being imperfect, partly because the chimneys for the final discharge of the fumes are too low, and partly because the arrangements are not perfect enough to allow coke ovens to be dispensed with.

2nd. Johnson's works at Greenhithe. This is a patented arrangement (1872, No. 1583). Mr. Johnson has a series of long arched chambers, the height of the arch being 6 feet. At one end of each chamber, and within the chamber, is a kiln, the open top of which is on the level of the floor of the chamber; it is of the ordinary shape and construction, and of capacity to burn from 20 to 22 tons of cement at a charge. At the other end of the chamber is an opening leading to the flue common to all the chambers, which after a course of some yards terminates in a chimney shaft 304 feet high from its base, the base being 50 feet above the level of the neighbouring river. The floor of each chamber is made of concrete, and along the top of the arch of each chamber are openings through which, by an appropriate disposition of conduits, slurry prepared by the Goreham process is run into the chamber to a depth of about 10 or 12 inches. After charging the chamber the openings are closely covered down. The hot air from the burning kiln has all to pass into and through this flue-chamber to reach the main flue leading to the chimney stalk, and in so doing dries the slurry sufficiently for the next charge. The kiln is charged with dry slurry directly from the chamber, and only the coke is introduced from without through an eye above the kiln. Each chamber, with its kiln, is an independent arrangement, complete in itself. The nuisance that gave rise to legal proceedings in respect of their works is so far abated that the principal complainants have made affidavits to the effect that they are no longer annoyed by the fumes.

3rd. At one of Messrs. Francis & Co.'s works at Cliffe (not the works complained of by the War Office authorities), a modification of the above arrangement, patented by Mr. De Michele (1876, No. 4922), has been successfully introduced. Plate IV. will serve to illustrate the arrangement, and assist also in the comprehension of that last described. In what I may term the Johnson-De-Michele arrangement, the flue chambers *A* are each 50 feet long, 15 feet across, and 5 feet high to the top of the arch, and each kiln, *B*, burns about 25 tons of cement at a charge. The arrangement differs from the Johnson arrangement in this, viz., that the roof of the chamber is so arranged as to be used for drying part of the slurry, which is not prepared by the Goreham process, but pumped up in a liquid condition on to the top of the chambers, in which situation it is protected by a shed above. The roof of one chamber is, on the top, divided off from the roof of the adjoining chambers by low brick walls, and so an angle *C* is

formed. The slurry is in part pumped into the chamber and in pa into the angles above. In this latter situation some deposition of th solid particles takes place: the more liquid portion is run into th chambers through shuttled openings provided for the purpose, and th thicker matter deposited is shovelled up on the top of the arches to dr The chimney stalk which receives the fume from the whole set of i chambers is 204 feet high. No nuisance appears to have been com plained of.

4th. At the works of Francis & Co., at Cliffe, near the Fort, i respect of which the injunction was issued, the arrangement adopted i that represented in Plates V. and VI. At the time when the injunctio was issued they were working ordinary open cone-topped kilns. Failin other methods of abating the nuisance, there has been raised above th tops of a series of nine such kilns in one set, a horizontal iron tube line with firebrick, having an internal diameter of 4 feet, and with this tub the open top of each kiln is made to communicate, the opening from each kiln being provided with a damper. From the middle of the tube a similar tube, having an internal diameter of 4 feet 6 inches clear rises vertically as a chimney an an elevation of 160 feet. The whole arrangement is light and comparatively inexpensive. It has completely obviated the nuisance complained of. There is an excellent draught in the kilns.

5th. At Messrs. Patrick's Cement Works at Dovercourt, where similar cone-topped kilns were formerly in use and occasioned nuisance, the nuisance has been obviated by carrying a flue downwards from near the top of each conical head to a large main flue running along the whole set of 12 large kilns, which flue terminates finally in a chimney shaft about 260 feet high, that is to say, high enough to carry the fume a long way above the residential parts of the neighbouring hill. Coke ovens are used at these works, but all their flues are connected with the same tall chimney shaft, and no nuisance is, I am given to understand, now complained of.

THE FIRING OF POTTERY.—SALT GLAZING.

Establishments visited.

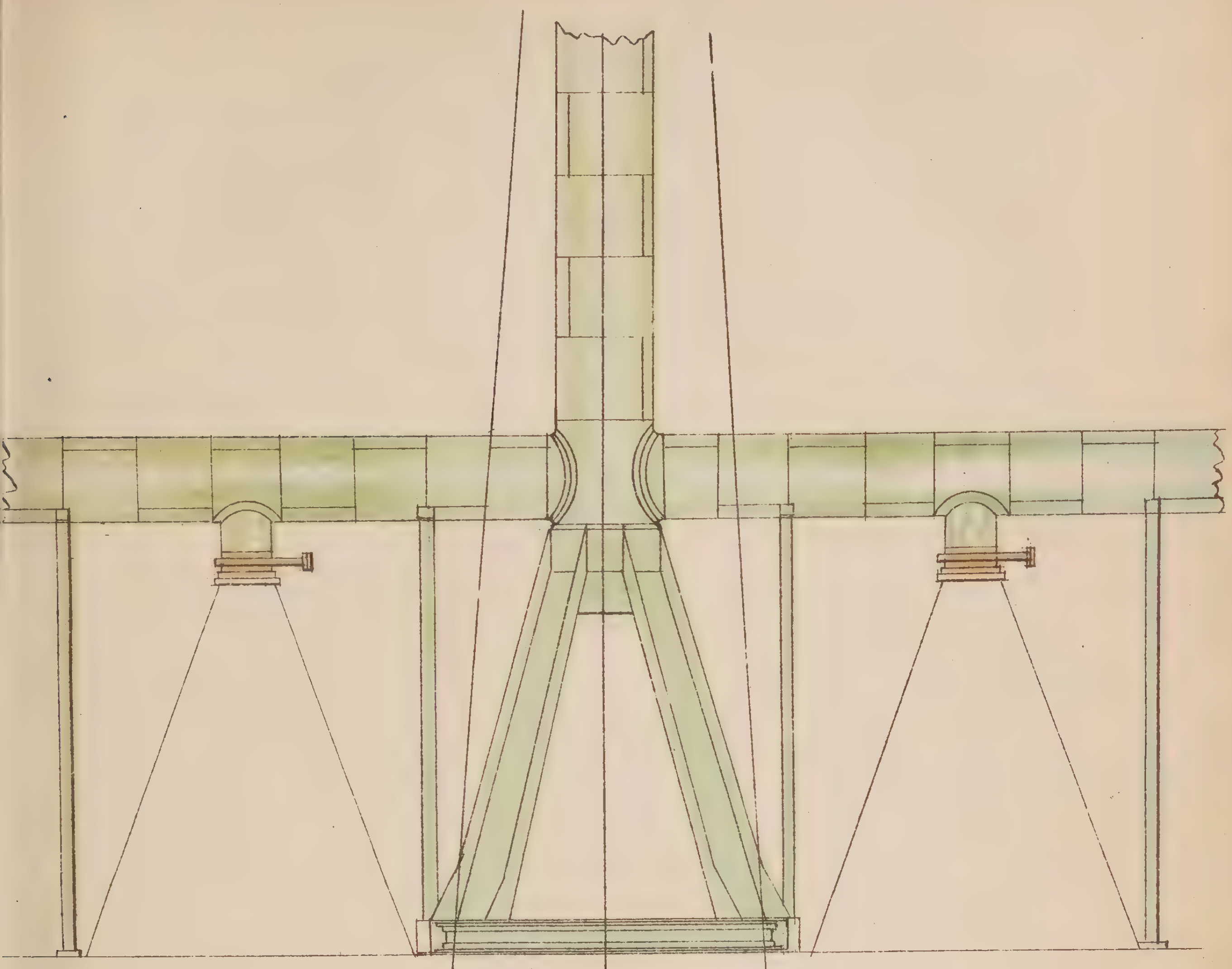
ESTABLISHMENTS VISITED.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Oct. 18, 1877 -	Minton - -	Stoke-on-Trent	Making bone ash.
„ 23, „ -	Cooper - -	Longton, Staffordshire.	—
„ „ „ -	Brough and Blackhurst.	Ditto.	—
„ „ „ -	Tams - -	Ditto.	—
„ „ „ -	Wileman -	Fenton, Staffordshire.	—
„ „ „ -	Cartwright and Edwards.	Longton.	—
„ „ „ -	Daisy-bank Pottery.	Ditto.	—
Jan. 25, 1878 -	Henry Doulton -	Lambeth.	—
April 9, „ -	Edward Brooke and Sons.	Huddersfield -	Fire-brick making.
Jan. 22, 1879 -	Henry Doulton -	Old Hill, Worcestershire.	Brick-making.
Feb. 25, „ -	Ditto - -	St. Helens, Lancashire.	—
„ „ „ -	Banks - -	Hanley.	—

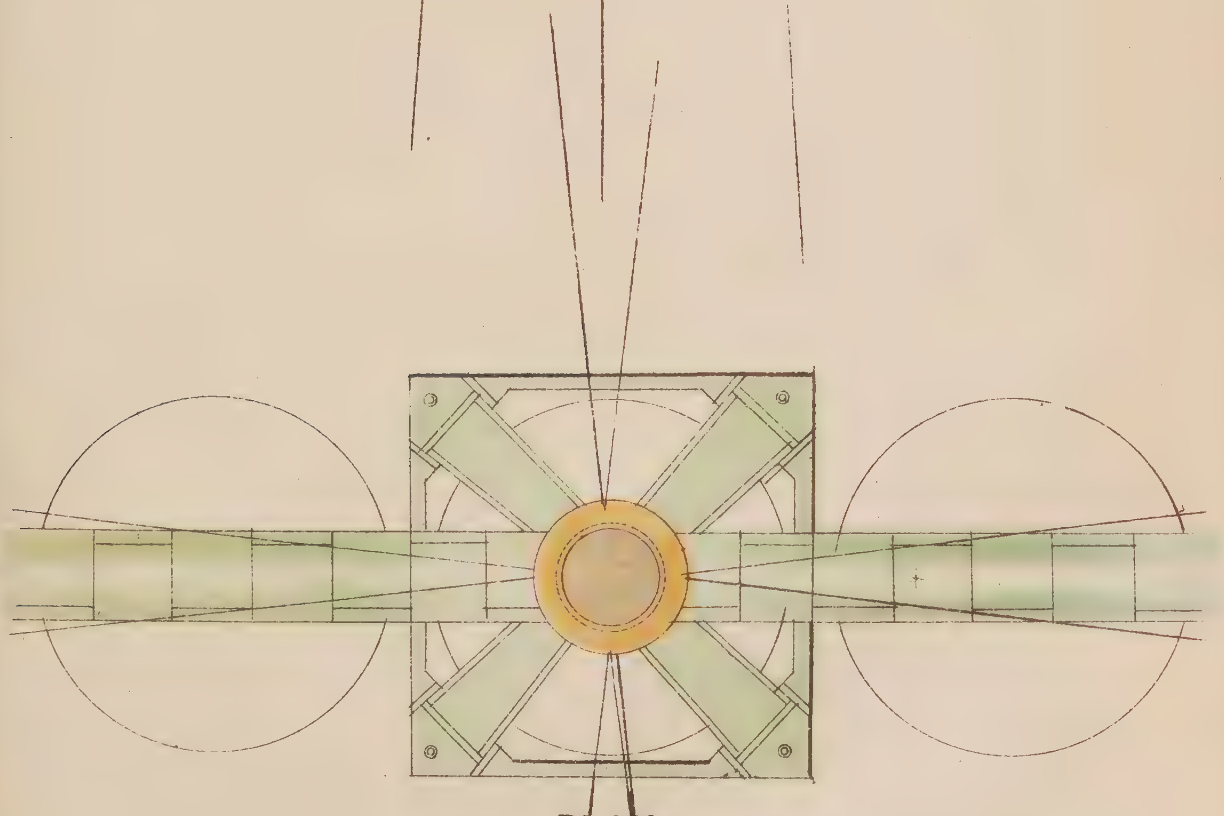
CEMENT KILNS OF MESS^RS FRANCIS & C^O AT CLIFFE, KENT.

DANGERFIELD. LITH. 22. BEDFORD S^T COVENT GARDEN.

FRANCIS & C^{os} CEMENT WORKS. ARRANGEMENT FOR PREVENTING NUISANCE FROM FUMES.



ELEVATION.



PLAN.

Scale $\frac{1}{12}$ inch to a foot

DANGERFIELD. LITH. 22. BEDFORD S^{T} COVENT GARDEN.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 25, 1879 -	Powell, Bishop and Stonier.	Hanley.	—
Mar. 4, " -	George Ash -	Ditto.	—
" 26, " -	Royal Porcelain Factory.	Worcester.	—
" " " -	Grainger -	Ditto.	—
April 2, " -	Hartley - -	Castleford -	Brick-making.
" 5, " -	Darfield Pottery Works.	Darfield, Yorkshire.	—
May 3, " -	Stiff and Sons -	Lambeth.	—
" " -	Charles Bastin -	Ditto.	—
" 13, " -	J. C. Edwards -	Cefn, North Wales	Brick-making.
" " " -	Ditto - -	Ruabon, "	Ditto.
June 16, " -	Wass and Sons -	Meerbrook, Ambergate, Derbyshire.	Ditto.
" 20, " -	Brandon Colliery	Durham.	Ditto. Colliery. Coking.

Manufacture of pottery.

I embrace within the term "pottery"—1. Articles of ordinary earthenware and china, and 2. Salt-glazed ware.

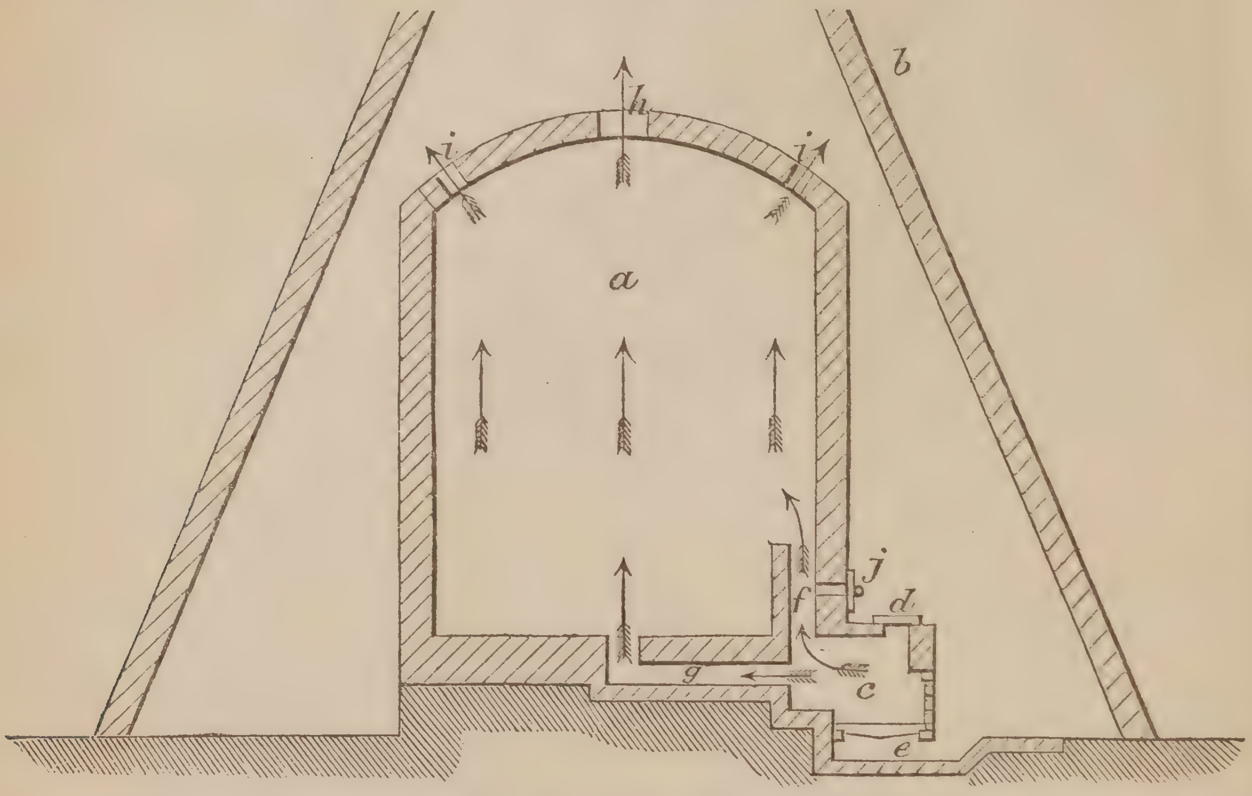
1. Articles of earthenware, &c.

1. *Articles of earthenware, &c.*, are first dried by a moderate heat, and are then subjected to their first firing, in what is termed a "biscuit oven." This firing occupies 48 or 50 hours, and an additional two days are occupied in cooling before the ware can be removed. When the ware leaves this oven it is in a hard but porous condition termed "biscuit." It is on the ware in this state that any pattern it is to receive is laid on. The pattern is printed with oil upon thin paper, and being laid smoothly upon the ware, it is absorbed by the porous surface. The paper is now washed off, and the ware undergoes its second firing known as "hardening-on," with the object of destroying the oil that has been absorbed. The ware is now dipped in the appropriate glaze, and when dry, is fired a third time in what is termed the "glost oven." The firing in this oven occupies about 18 hours. The "biscuit oven" and the "glost oven" are of similar arrangement, the only difference being that the latter is usually smaller than the former. In describing the biscuit oven I may therefore be regarded as describing a glost oven also. The articles to be fired are first carefully packed in oval coarse boxes or deep trays made of strong fire-clay and termed "saggers," which are then systematically piled up, one on the top of another, from the bottom to the top of the oven, column by column, until the oven is completely filled. By this arrangement the flame and heated air that enter the oven are prevented from coming into immediate contact with the contents of the saggers; and when glost is fired, the intervals between the saggers above and below are in addition closed or luted with clay. Fig. 6 represents roughly a section of an ordinary old-fashioned biscuit oven, as it may be seen in many of the less modern works in the Staffordshire potteries.

The oven *a* is situated within a conical erection or hovel *b*. Surrounding it at the base are 8 or 12 fireplaces ("mouthers") arranged as shown in the diagram *c*, each having a feeding hole *d* above, which can be covered with a tile *d*. In the diagram an ashpit *e* is represented, but in the oldest form of oven there is no ashpit. From each fireplace the flame passes in two directions, namely, upwards into the kiln through the "bag" or little flue *f*, and horizontally by a flue *g* into the middle of the oven at its floor, termed the "well-hole." From the several

bags, and from the central opening, the flame and heated air rise through the oven and pass out by a central opening *h* in the roof, and by shoulder

Fig. 6.



openings *i i* round the roof not far from its edge. The smoke, if any, is discharged from the tapering open summit of the hovel. In the wall of the oven, opposite each bag, is an air opening *j*, provided with a sliding cover, by which the admission of air can be regulated.

But there are other kinds of biscuit ovens which are closed in at the top, except during cooling, emptying, and recharging. These closed kilns are, in the best class of works, gradually superseding the sort of kilns I have described. There are several kinds of close ovens in use. The most common form is similar in principle to the close brick kiln described and figured at p. 55, that is to say, the flame and heated air pass up "bags" from the several fireplaces round the oven, and after reaching the roof, descend to a flue commencing in the middle of the floor of the oven, or at various other parts of the perforated floor. The patent oven known as Robey's oven, is constructed on this principle of down-draught, and is in use in several works in the Staffordshire potteries; but it differs from the common down-draught oven, inasmuch as the central opening in the floor is not used to draw off the heated air, but for its introduction, as in the ordinary old fashioned up-draught oven, the air passing out of the oven by other apertures in the floor between the central opening and the sides of the oven. These apertures lead to a circular flue that discharges itself into a chimney shaft outside, which may be made to serve for two or more such ovens. It is observable that little modification is required to convert an ordinary up-draught oven into one on Robey's principle. Plate VII., copied from the patent specification (1873, No. 970), represents the main points of construction. The arrows indicate the course of the currents of hot air. Another form of closed kiln which is coming into use is that of Mr. Minton's, which also has been patented (1873, No. 1709). Plate VIII. shows its construction. The following is the patentee's description of this oven :—" *a a* are the fire bars ; *b b* the doors through which the fuel is " supplied ; *c c* the fireplaces or 'bags in which the combustion takes

ROBEY'S POTTERY OVEN.

FIG. 2.

Horizontal Section in line AB. Fig. 1.

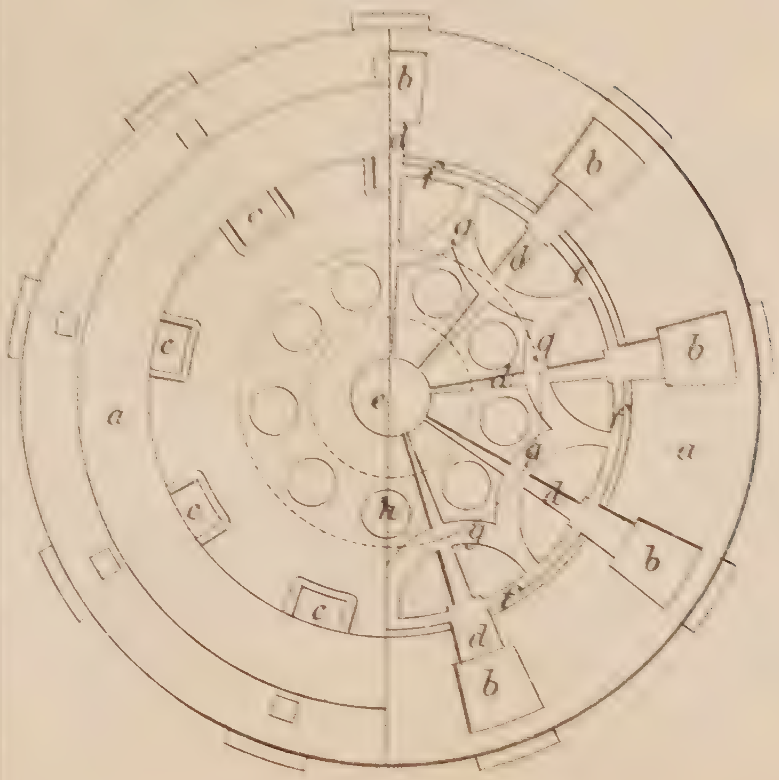
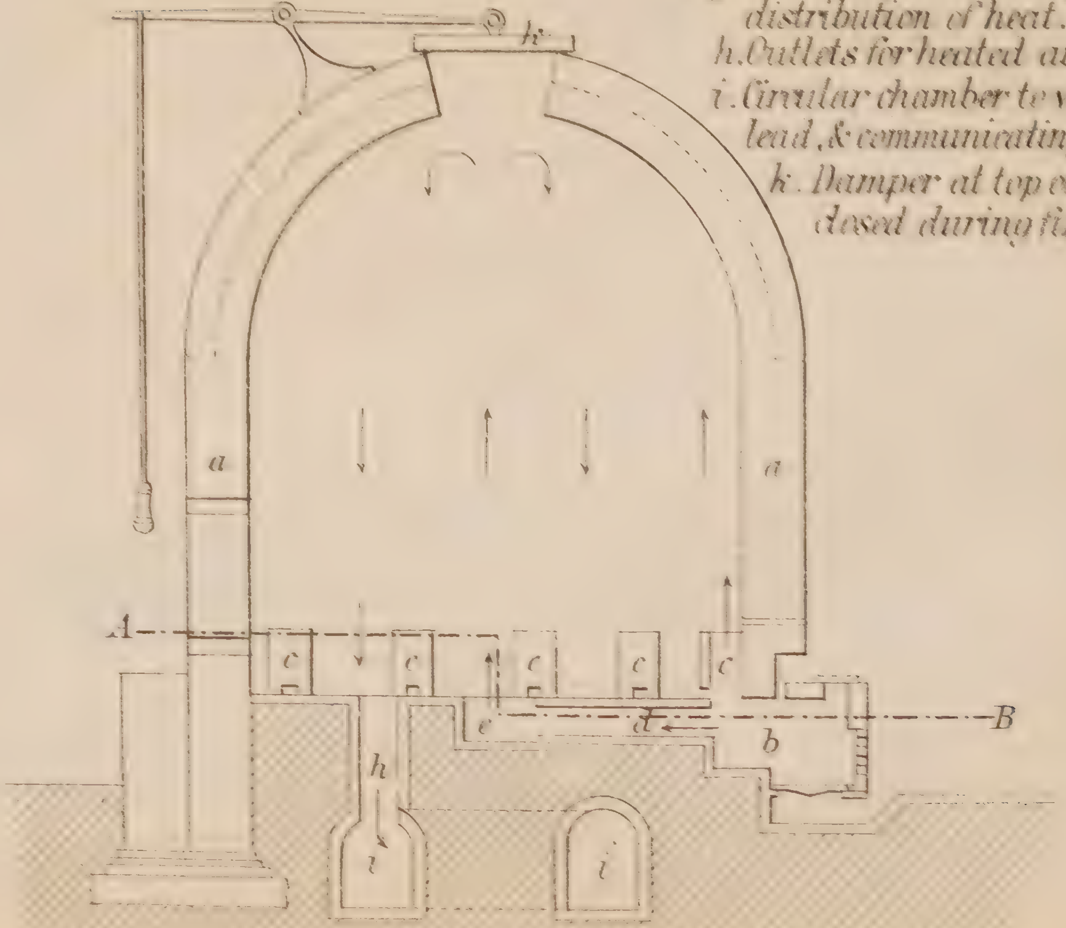


FIG. 1.

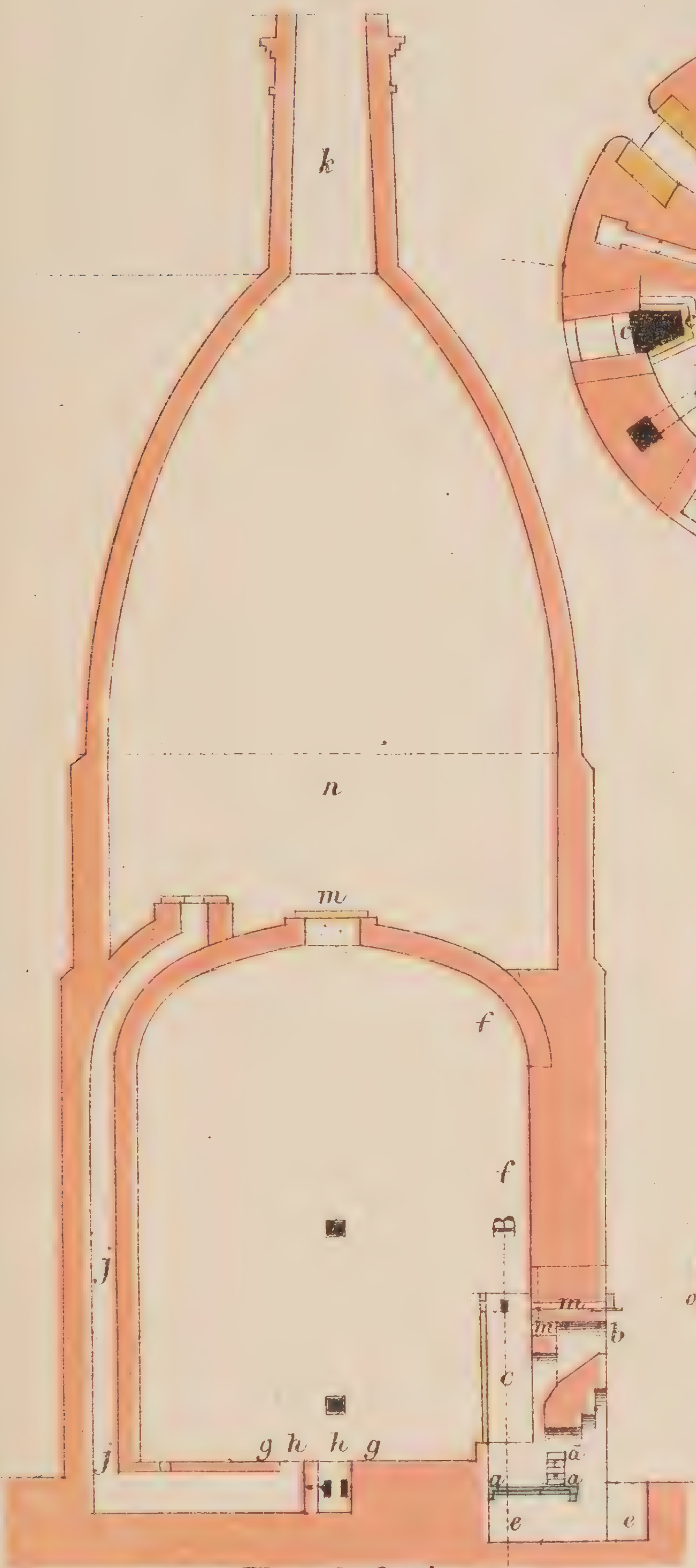
Vertical Section.



a. Walls of Kiln.
b. Fire holes.
c. Side flues or "bags" by which part of flame enters.
d. Radial flues to central opening.
e. Central opening for admission of part of heated air.
f. g. Connecting flues to equalise distribution of heat.
h. Outlets for heated air.
i. Circular chamber to which outlets lead, & communicating with chimney.
k. Damper at top of kiln closed during firing.

Dangerfield Lith. 22 Bedford St. Covent Garden

MINTONS PATENT OVEN.



Vertical Section
Figure 1.

Plan above the bars

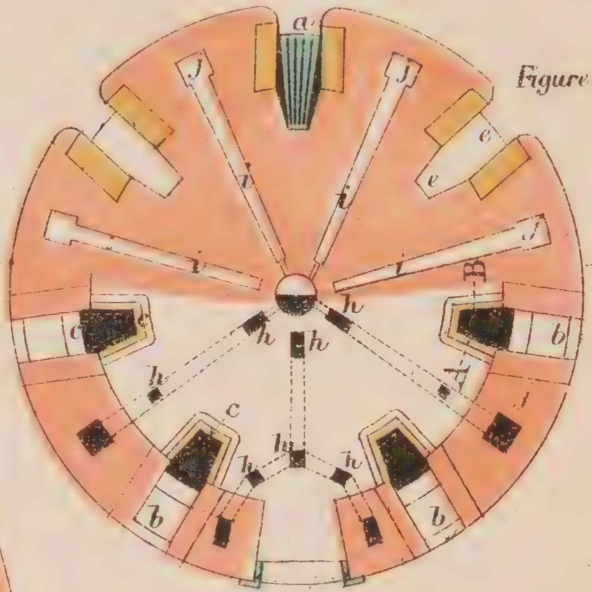
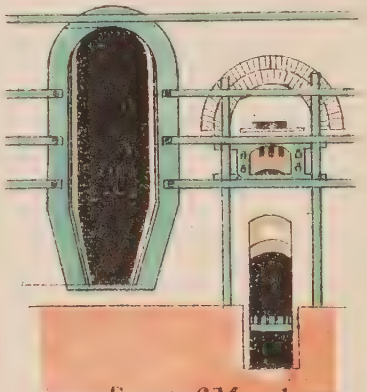
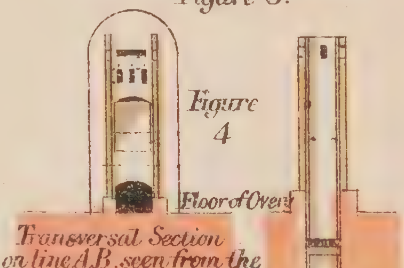


Figure 2.

Plan above the Chute

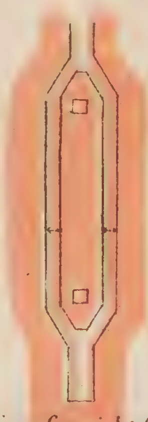


Front of Mouths
Figure 3.



Transversal Section on line A.B. seen from the inside.

Transversal Section on line A.B. seen from the outside.



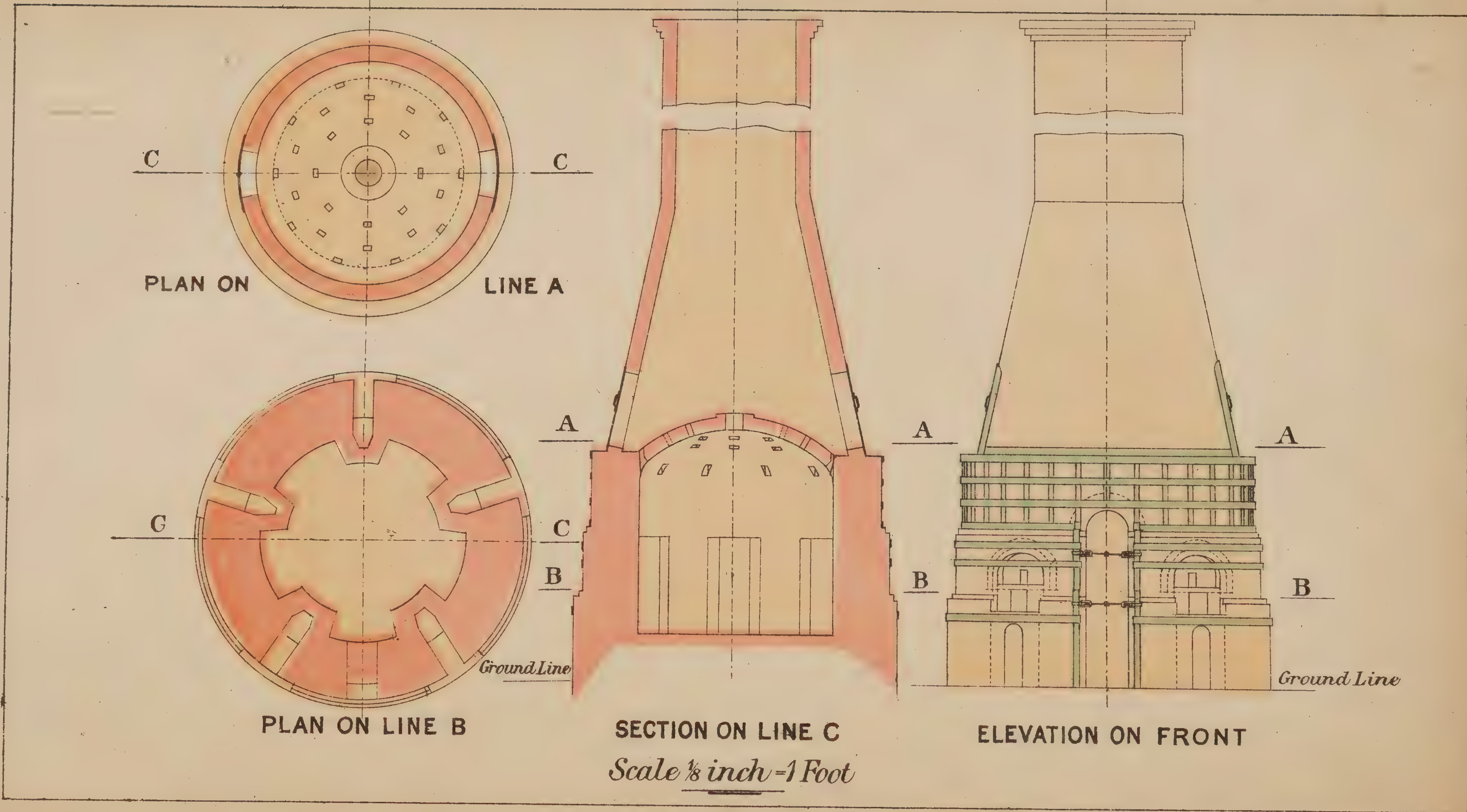
Section of upright flues where they meet the Trial holes.

Figure 5.

Scale, 1/8 of an Inch to 1 foot.

Dangerfield Lith 22. Bedford St. Covent Garden.

KILN FOR FIRING SALT GLAZED WARE AT MESS^RS. DOULTON'S LAMBETH WORKS.



Scale ⅛ inch = 1 Foot

Dancerfield. Lith. 22. Bedford St. Covent Garden

"place, and in the lower front of which some loose bricks *d* are placed to "prevent the coals falling in ashpits *e e*. When the oven is firing, the "flame produced in these bags is directed towards the upper part of "the oven *f f*, and as there is no opening in the vault through which "the heat might escape, the flame is compelled to travel in a downward "direction to reach the floor *g g*, where a number of openings *h h* are "disposed. These openings give access to several horizontal flues *i i*, "and from these the gases reach the upper chamber in passing through "the upright flues *j j* existing in the thickness of the walls. From the "second chamber the final escape of the gases is effected by the outer "chimney *k*. Above the doors used for the supply of coals, the small "openings *m m* have for object to introduce the quantity of air neces-"sary to effect a perfect combustion, and they are regulated according "to the quality of the fuel. A cooling flue at the base of the oven "which communicates outside is kept shut all the time the oven is "firing, and is open afterwards to assist in cooling. The damper *m* in "the centre of the vault is also removed after firing for the same "object. One object of the upper chamber *n* is to collect the gases "from the upright flue *j j*, so that the outer chimney, acting on all "of them at the same time, equalises the draught of those which "might be backward or in advance. By reducing the diameter of the "outer chimney, the flame may be brought into the second chamber, or "by enlarging it, a complete combustion may be effected in the lower "part of the oven, so that carbonic acid only will be found in the upper "chamber." The advantages claimed for this oven are that "The old "feeders or mouths are dispensed with, the combustion of the coals "being entirely effected inside or in the hold of this oven, so that the "heat from the coke or the gases has a more direct effect on the saggers "containing the ware with which it comes in contact (than in the old "mode of arrangement); thus a considerable reduction in the quantity "of fuel required to fire the ordinary ovens is realised. Besides, by "the addition of a second chamber on the top of the oven the necessity "of surrounding the oven by a second building called a hovel is "avoided."

The "hardening-on" kiln and the "enamel" kiln are constructed alike. This kiln is in fact a close chamber or muffle-kiln of fire brick, and is heated by surrounding flues from a fire beneath the kiln. The kiln is supplied with shelves on which the articles to be fired are supported—saggers not being used. When about to be fired the entrance doorway is carefully bricked up. The duration of the firing is about 12 hours.

2. Salt glazed ware.

2. *Salt glazed ware* is fired sometimes in open kilns, that is to say, in kilns from which the heated air escapes by openings in the roof of the kiln, as at the several pottery works in Lambeth, and sometimes in closed kilns, that is to say, in kilns the openings in the roof of which, necessarily provided for the convenience of "salting," are closed except during the salting process, and from which the hot air escapes to a chimney outside through apertures in the floor of the kiln. Such close kilns as these are in operation at Mr. Doulton's Works at Old Hill and St. Helens, at E. Brooke and Son's Works at Huddersfield, and at several other works I have visited. Plate IX. illustrates the arrangements of one of Mr. Doulton's open salt glaze kilns at the Lambeth Potteries. The ware is arranged in the kiln (without the use of saggers) in such a way that the flame from the fires can pass readily among the several pieces. Coal is used as the fuel for the most part, although Mr. Doulton says that coke is also used to some extent. The time occupied from first lighting up of the kiln until the ware is in a condition for salting is about 2½ to 4 days, according to the size of the

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kiln and other circumstances. The workman judges from the aspect of the contents of the kiln when it is in a proper condition for salting, and then salt is thrown in with a shovel at the several openings in the roof, and also at the fireplaces below. At some works one salting is found to be sufficient; in other works the salting is repeated at intervals, once or even twice, the whole time of salting occupying in the last case about two hours. When the ware is sufficiently salted, the fires are allowed to go out. An abundance of white fume escapes during the salting process, for about 20 minutes after each salting, and passes off by the chimney. When the ware is cold it is found to have upon the surfaces which have been exposed to the action of the salt, a glaze of extreme tenuity, and the colour of the ware, if properly salted, is uniform. According to the size of a kiln, it is charged, salted, and discharged once a week or once a fortnight.

Nuisance; from ordinary pottery works;

The only effluvium nuisance occasioned by ordinary pottery making (earthenware, china, Parian ware, &c.) arises from the smoke evolved from the chimneys. These are almost invariably low, being in fact the top openings of the hovels in which the ovens are placed. In the pottery district of North Staffordshire such chimneys may at any time be seen vomiting forth black smoke, which, not being much heated and not passing away with any remarkable velocity, does not rise high into the air, but quickly falls, filling the streets and roads to such an extent as sometimes to impede vision beyond a distance of a few yards.

The enamel ovens are a source of still greater nuisance than the biscuit ovens, since the chimneys are lower, and the black smoke is consequently emitted at a lower level. It is impossible to say to what extent this smoke which pervades the pottery towns, more or less at all times, and especially in some conditions of the weather, affects public health. Certainly it is not conducive to mental exhilaration, and inasmuch as it fouls the skin and clothing, and sometimes compels householders to close the windows of their houses to keep it out, must be on those accounts alone unfavourable to public health, especially among children and among classes of persons who are not much given to ablution. Such a smoky atmosphere as prevails habitually in some of the pottery towns, may not demonstratively shorten life, and diseases may not be distinctly traceable to its operation, yet it is impossible to doubt that it is injurious in at any rate an indirect manner, by favouring the operation of other more obvious causes of disease.

from salt-glazing.

The smoke from salt glazed works is open to the same imputation, but in addition there is here to be considered the white fume that proceeds from the chimneys during the salting process. It is true that this is a less constant nuisance than smoke; it is only an occasional nuisance, lasting as long as the salting lasts, and then coming to an end until another kiln is salted. At some works the salting is only performed on certain days of the week. The complaints that have been made of this particular white fume, which is heavy, soon falls, and is apt to sweep (especially in some conditions of the atmosphere) along the surface of the ground for some distance, are that it is acid and irritating to the organs of respiration, especially those of persons who are suffering from pulmonary affections. It is said to produce in such persons a sense of oppression at the chest, bronchial irritation, and cough. It is impracticable to demonstrate that in any other way these fumes are injurious to health or produce actual diseases.

The fume consists in great part of salt, but also it contains hydrochloric acid. Dr. Angus Smith, in a minute he wrote with respect to a complaint of nuisance from the Lambeth Works in 1876, says that Mr. Fletcher has found the quantity of acid emitted to be 44 grains in

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a cubic foot of the smoke. This would apply, I assume, to the period of salting only. (For further information see the postscript to this article.)

Prevention of nuisance; from ordinary pottery works.

It is perfectly practicable to reduce very greatly the smoke nuisance from pottery ovens and kilns; indeed it has of late years been reduced considerably in the pottery towns of North Staffordshire. To this fact I have the testimony of medical men practising there, and of other old residents. And, moreover, I have myself observed a change for the better in this respect since I first became acquainted with these towns in 1872. Even where the old fashioned kiln with up-draught is used, it is practicable to work with the production of much less smoke than it is customary to emit. The smoke most complained of is given off during the first 24 hours of the firing, before the ware has become ignited, and again when fresh coals are put into the fires, which is done at intervals of about 2 or 3 hours; the issue of black smoke then commonly lasts for about half-an-hour. Upon this subject I had an instructive conversation with Mr. Tams, a manufacturer at Longton, who has some of these old ovens in use, as well as some of more modern construction. He said that his practice, by which a good deal of the smoke is avoided, is, when lighting a kiln, only to light up at first the alternate fires and to let them burn up well, and then to light the others, and that in this way he manages to consume at any rate a portion of the smoke. After this, instead of "bating" (*i.e.* stoking) all the fires at one time, he "bates" them alternately, and by opening the door of the fireplace after bating, he directs the smoky flame towards the centre of the kiln, where it meets with hot air from the other fires in full combustion, and so the smoke becomes in a great measure or wholly burned. During my visit to his factory he had the fires bated in this way, and there certainly was little or no issue of smoke from the top of the hovel. He further said, that one cause of the long continuance of smoke when the fires are first lighted is, that sometimes the ware has not been thoroughly dried before being fired. But it is not an easy thing to induce the firemen so to break through their old traditions as to "bate in any other way than they have been accustomed to all their lives."

Again, at the Royal Porcelain Works at Worcester, where none but up-draught biscuit ovens are in use, the quantity of smoke that issues is only trifling in amount after they have once been fully ignited.

Unquestionably, the modern ovens and kilns with a down draught have an advantage over the old up-draught ovens in the matter of smoke. This is the case even with the commonest form of such a kiln, putting aside all question of patent kilns. It will smoke for a time after being first lighted up, but when once the charge is ignited no smoke at all, or none worth noticing, should issue when the fires are bated, and none will issue if ordinary care be used in regulating the draught. The great advantage of the two patent ovens or kilns that I have described is their economy of coal; and, obviously, the less coal that is used, other things remaining the same, the less smoke is likely to be produced. Mr. Robey claims for his oven a saving of fuel to the extent of one-third or one-half of that ordinarily used, and Mr. Minton claims for his oven a saving of 40 per cent. in the case of his biscuit ovens and 50 per cent. in the case of "glost ovens." It is quite possible that both these patentees may claim more in this respect than actual experience will warrant—of that I can say nothing—but it is a fact that a very large saving is effected. There is the additional advantage in the case of Minton's oven that by the use of the upper chamber the waste heat of the oven may be utilised, and thus, to some extent, the nuisance of the "hardening-on" oven may be obviated.

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At the Royal Porcelain Factory at Worcester the smoke-nuisance from the enamel ovens has been wholly done away with, by connecting the flues from a large number of such ovens with two chimneys, one 80 feet high, and the other 120 feet high. When I visited the establishment these ovens were fully at work, and I was struck by the small amount of smoke that was issuing from the chimneys, the contrast being so great to what I had been accustomed to see in Staffordshire. Mr. Binnes, the managing partner, informed me that he had tried to use gas (from the town supply) to heat their ovens, but that something (watery vapour, sulphurous acid, or some other matter) which passed from the flues into the muffle oven had injured the ware. He says he is still hopeful of overcoming this difficulty.

The principle of Mr. Minton's patent, so far as the mode of constructing the fireplaces is concerned, is applicable to muffle ovens, and by its application to such ovens at Mr. Campbell's Encaustic Tile Works at Stoke the issue of smoke has been considerably reduced.

from salt glazing.

An attempt was some little time ago made by Mr. Doulton, at his works in St. Helen's, to arrest the fume from the salt-glazing process by means of a coke scrubber supplied with water on the same principle that has been successful in dealing with the hydrochloric acid fume at alkali works. It was made under the direct superintendence of Mr. Fletcher, one of the sub-inspectors under the Alkali Acts, whose experience and familiarity with this method of condensation peculiarly fitted him for grappling with the difficulties likely to be met with. There was put up at these works a tower 25 feet high and 2 feet 6 inches wide (sectional area 4·91 feet), constructed of stoneware pipes, and filled with stoneware balls 3½ inches in diameter, and an arrangement was made for water to flow down it. During the process of salting the hot air or fume from the flues proceeding from the bottom of the kiln, which at ordinary times passed directly into the chimney shaft 60 feet high, was damped off and made, by means of a branch flue, to pass up this tower from the top of which it entered the chimney. Chemically, the attempt was successful. Mr. Fletcher informed the Noxious Vapours Commission that he succeeded in condensing three fourths of the acid coming off, and in suppressing almost entirely the white fumes. In a minute made upon the Lambeth papers, in 1876, Dr. Angus Smith, referring to this experiment by Mr. Fletcher, says: "The result is that " the escape can be reduced under 0·2 grains per cubic foot and some" times to 0·" Technically, the experiment was less successful. There are two difficulties to be overcome; one is the heat of the vapours sent into the condenser, and the other the absolute necessity of not interfering with the draught through the kiln at the time of salting. A diminution of the proper draught is fatal to successful salting, since it results in two defects which lessen the saleable value of the ware, viz., dark stains, or at any rate a lack of due uniformity of the colouring of the ware, and roughening of the surface by gritty matter which, instead of passing away, sticks upon the glazing of the ware. Dr. Angus Smith says, in the minute above referred to, that Mr. Fletcher tried several kinds of steam jets with the object of assisting the draught: that which succeeded best was Körting's steam jet, the working parts of which are made of platinum to avoid corrosion. When I visited these works in February last I saw the tower, but its use had been abandoned for the reason, the manager informed me, that even with the aid of the powerful steam jet the interference with the draught was such as to deteriorate the ware (drain pipes); it would be still more injurious in the case of finer wares. Dr. Smith quotes the opinion of Mr. Fletcher that the condensing tower ought to be 30 feet high with a sectional area of

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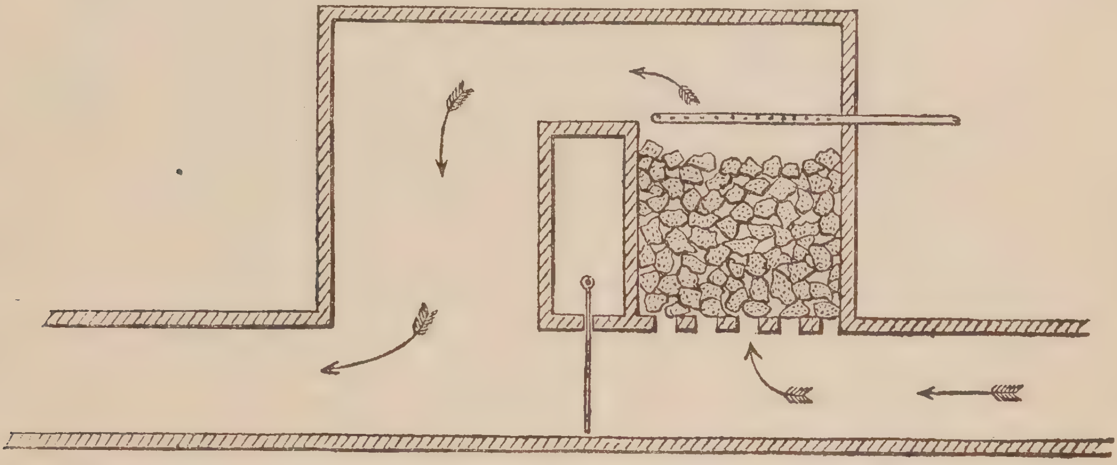
25 square feet (=5 feet square or 5 feet 8 inches round). He appears to be hopeful of success at some future time. The result of an experiment made by the proprietor of another establishment was not more favourable. With a view to do all in his power to satisfy persons who complained of the noxious vapours, he erected a brick chamber 12 feet high with an internal diameter of 6 feet 3 inches × 4 feet 3 inches, which he filled with coke and supplied with jets of water by means of a perforated pipe, as shown in the rough diagram Fig. 7. At the time of salting, the fume

Fig. 7.



and hot air were diverted from their direct course to the chimney by means of a damper in the flue (4 feet × 4 feet 6 inches in measurement), and sent up through the scrubber, from whence they descended through a similar but empty chamber to the flue. Chemically, again, the plan was successful, since the proprietor of the works informed me that no hydrochloric acid was capable of being discovered in the air of the second chamber by a chemist sent by the complainants to examine into the efficiency of the apparatus. But, technically again, it was a failure for the same reasons that caused the scrubber to be abandoned at Doulton's Works. The smoke and fume from all the kilns, 13 in number, are now discharged from a tall chimney shaft 315 feet high, and I am informed that complaints of nuisances have ceased. (*See* further p. 293).

The quantity of salt habitually used in the salting process is very largely in excess of what is needed to supply soda for the glaze. It is necessary to use an excess on account of the inevitable loss of some of the salt by volatilisation; but it became a question with Mr. Doulton and others whether the excess used was not much greater than was absolutely necessary. The result of experiments in reducing the quantity has been that it has been diminished by about one-half, with equally good results and with a diminution of the visible fume by one half. Of course the same quantity of hydrochloric acid is discharged. Mr. Doulton says that, whereas formerly they used 5 cwt. of salt to a kiln, they now use but 2 cwt.: he does not think the quantity can be reduced any further. The actual quantity of salt requisite will depend upon the size of the kiln and the nature of the clay of which the ware is made, ware made with fire-clay requiring more salt than ware made with other clays. Some charges may, I understand, be salted sufficiently by the use of half a hundredweight of salt.

TABLE of RESULTS of 22 EXPERIMENTS made by DR. BERNAYS on the FUMES given off during SALT GLAZING at MR. DOULTON'S POTTERY WORKS, LAMBETH. (*See* p. 87.)

A.—DURING SALTING OF UPPER HOLES.

From No. 21 Kiln, " Fancy Goods," one of the smallest.

Number of Experiment.	Date.	No. of Kiln.	Quantity of Gas Drawn.	Duration of Drawing.	Duration of Salting of Upper Holes.	Solids.	Ash.	Na Cl.	Volatile H Cl.	Acidity as H Cl.	SO_3 (fixed.)	SO_2 (Volatile.)	Lead.	Iron.	Remarks.
			Gallons.	Minutes.	Minutes.	(In grains per gallon of gas drawn).									
I.	March 7th	21	9	—	13	·180	—	·116	·027	·050	·034	—	Trace	Trace	A good deal of soot. Washings filtered for analysis.
II.	" "	"	7	—	"	·096	—	·050	·027	·033	·018	·026	Minute trace	Absent	Ditto.
III.	" 14th	"	7	20	15	·260	—	·056	·048	·097	·077	·026	Ditto	Almost absent	Little soot. Yellow substance.
VIII.	" 21st	"	"	40	"	·291	·273	·147	·115	·175	·066	·026	Trace	Trace	Not much soot. Soot at end yellowish. A small quantity of the yellow body. Centre hole of dome.
IX.	" "	"	"	48	"	·177	—	·058	·098	·081	·016	·024	Minute trace	Distinct trace	Side hole. Not much soot.
XI.	" 28th	"	"	41	14	·237	·104	·029	·090	·042	·032	—	Ditto	Nearly absent	Not much soot. Side hole.
XII.	" "	"	"	33	"	·280	·186	·071	·072	·129	·122	·004	Trace	Minute trace	Not much soot. Centre hole.
XIV.	April 4th	"	"	38	About 15	·147	·119	·020	·050	·061	·040	—	Almost absent	Ditto	Much soot. Side hole.
XV.	" "	"	"	40	"	·371	·290	·137	·095	·121	·051	·008	Distinct	Trace	A good deal of soot. Centre hole.
XVI.	" 18th	"	"	40	12	·179	·157	·064	·065	·081	·019	·025	Very distinct	Ditto	Not much soot. Centre hole.
XVII.	" "	"	"	60	"	·130	·089	·022	·045	·064	·013	·037	Trace	Ditto	Side hole. Little soot. At this hole there was less visible fume than at some of the others.
XIX.	" 25th	"	"	—	15	·266	·243	·148	·065	·105	·021	·045	Ditto	Almost absent	Centre hole. Moderate amount of soot.
Average	—	—	—	—	—	·218	·183	·076	·066	·086	·042	·024			

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					From No. 20 Kiln. Smaller than No. 21. "Fancy Goods."										
XVIII.	" "	20	7	—	10	·531	·398	·235	·130	·194	·060	·020	Almost absent	Very minute trace.	A good deal of soot. Side hole. This appeared to be a heavier salting than No. 21 kiln.
					From No. 6 Kiln. Larger than the above. "Common Chemical Ware."										
V.	March 20th	6	$5\frac{1}{2}$	35	About 22	·327	·203	·070	·111	·165	·111	·054	Minute trace	Very distinct	Much soot. Yellow body not obtained.
VI.	" "	6	$10\frac{1}{2}$	45	"	·449	·388	·244	·155	·248	·082	?	Very minute trace.	Very distinct, mostly ferric.	Ditto.
					B.—DURING SALTING OF LOWER HOLES.										
XXI.	May 2nd	21	2	20	Lower at intervals during 20 minutes.	·357	·287	·193	·034	·085	·014	·026	Absent	Absent.	Variable amount of soot.
					C.—DRAWN AFTER SALTING, WHEN MAIN FUMES ENDED.										
V.	March 14th	21	7	—	—	·168	—	·011	·015	·032	·091	·034	Ditto	Minute trace	Twenty minutes interval between this and No. III. Very little smoke. Not much soot. A little of the yellow waxy body.
VII.	" 20th	6	$3\frac{1}{2}$	35	—	·159	—	·044	·033	·064	·071	·028	Ditto	Absent	Not much soot. Yellow body not obtained.
X.	" 21st	21	"	15	—	·093	·075	Trace	·016	·032	·022	·053	None	Nearly absent	Centre hole. Very little or no soot. No yellow body.
XIII.	" 28th	21	"	30	—	·151	·120	·013	·033	·020	·110	?	Absent	Absent	Centre hole.
XX.	May 2nd	20	7	35	About 12	·133	·082	·055	·029	·040	·018	·005	Almost absent	Distinct, mostly ferrous.	Salted at 12.30, hence $2\frac{1}{2}$ hours interval? no visible fumes.
Average of results after salting No. 21 Kiln				-	-	·137	·120	·012	·021	·028	·074	·043			
					D.—BEGINNING TO END OF SALTING. UPPER AND LOWER HOLES.										
XXII.	May 9th	7	12	20 lower 53 upper	Lower 5 Upper 13	·216	·204	·103	·068	·123	·019	·018	Minute trace	Distinct, all ferrous.	A large kiln; common chemical ware. A good deal of smoke and soot. Decanted for analysis.

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Postscript.

Postscript.

Feeling the great need there was of accurate information respecting the chemistry of salt-glazing, and as to the nature of the fumes given off in the process, I suggested to Mr. Henry Doulton the desirableness of a special chemical investigation of the subject being instituted. He at once undertook, at his own expense, to instruct a professional chemist to make it. He selected for this purpose (with my full concurrence) Dr. Bernays, Professor of Chemistry at St. Thomas's Hospital. I append the results of the inquiry made by that gentleman during the months of March, April, and May, 1879.

Report by Dr. Bernays.

Report of Dr. Bernays.

Experiments on the Fumes emitted during the Salt-Glaze Process, 1879.

Coals used.—The specimens were very various in size, big lumps mixed with a good deal of dust. White streaks of carbonate of lime occurred; pyrites in veins, lumps, and laminæ was plentiful, some of the lumps being in great part made up of it. Hence the procuring of a fairly average sample was very difficult, and some of the earlier specimens examined showed evidently a bias towards pyrites in their selection. The results may be useful in illustrating the variations.

—	—	Yield of Coke.	Water.	Ash.	Sulphur in Ash.	Volatile Sulphur.	Total Sulphur.
Tunstall -	1. Small - -	71·94	2·06	1·74	0·03	0·72	0·75
Ditto -	2. Large - -	67·51	1·19	—	—	—	2·93
*Ditto -	3. Small - -	63·86	0·75	1·87	0·22	4·20	4·42
†E. Wylam -	1. Large - -	82·51	1·98	2·20	0·19	4·85	5·04
Ditto -	2. Small - -	75·66	2·98	4·99	0·18	4·86	5·04
Ditto -	3. Small - -	71·84	2·99	2·48	0·06	4·26	4·32
Ditto -	4. Large, "pyrites visible."	—	—	—	—	—	4·63

[Note.—The total sulphur in the case marked * was determined by fusing in a silver dish with a mixture of sodium carbonate and chloride, and potassium nitrate; that marked † was treated similarly, but with pure potash, sodium chloride, and potassium nitrate: the rest were oxidized by heating them, in *very fine* powder, with nitric acid and potassium chlorate.]

The results on the whole show that East Wylam contains more ash and volatile sulphur, and somewhat more water than Tunstall. The specimens were collected at Messrs. Doulton's, Lambeth, December 5th, 1878.

To obtain a fairer estimate larger quantities were obtained from various potteries in February 1879, average samples taken from these by breaking pieces from all parts and including a corresponding amount of dust (which in some cases contained much dirt), and the sample, now about two pounds, broken up and thoroughly mixed by powdering and sifting. The following are the results :—

—	Pottery.	Yield of Coke.	Water.	Ash.	Sulphur in Ash.	Volatile Sulphur.	Total Sulphur.
Tunstall -	Doulton's, Lambeth	—	1·10	—	0·10	1·73	1·83* 1·97†
E. Wylam -	Ditto - -	70·31	1·46	3·97	0·12	2·22	2·34*
Ditto -	Thomas Smith & Co., Canal Pottery, Old Kent Road -	—	1·91	—	0·13	2·38	2·51*
Ditto -	Union Stone Potteries, Vauxhall Walk, Lambeth, S.E., Chas. Bastin, Feb. 6th 1879.	—	0·83	—	0·16	3·43	3·59* 3·71†

Those marked * were oxidized by heating in *very fine* powder with nitric acid, and adding small portions of potassic chlorate until all carbonaceous

matter was oxidized, and the solution was of a clear yellow color, with a *white* siliceous sediment. Those marked † were burnt in a combustion tube with sodium carbonate, potassium nitrate, and a little chlorate.

Here again *East Wylam contains the most volatile sulphur.*

It was stated that "Tunstall coal injured many of the colours of the fancy or artistic ware," and that "the manganese glaze was blackened by it in the lower tiers, and nearly "bleached above." "The relative prices of the two coals varied with the market: at present Tunstall was the cheaper, but this had been sometimes reversed."

Coke.—Samples finely powdered and dried. They were spongy and brilliant in lustre. The second was carefully averaged, small and large together.

Pottery and Date.	Sulphur in Ash.	Volatile Sulphur.	Total Sulphur.	Ash.
Doulton's, December 1878 - - - -	0·17	1·47	1·64	—
Ditto February 1879 - - - -	0·24	1·62	1·86	6·99

Salt.—Two kinds of salt were sent from Messrs. Doulton's:

1. "*Bumstead,*" of a rather dirty white colour, coarse grained, and moderately dry to touch; this is said to be "too strong:" and
2. "*Weston's Worcester salt*"—the one usually employed—of a cleaner appearance than the former, but a certain amount of visible dirt.

Their composition was as follows:

	Bumstead.	Worcester.
Lime - - - -	0·20	0·28
Magnesia - - -	none	0·03
Sulphur trioxide - -	1·37	0·78
Water - - - -	6·31	8·02
Sodium chloride - -	92·65	90·96
	100·53	100.07

The sulphur present was wholly in the form of sulphate. Nitrates were absent. There was no appreciable silica.

CLAYS (from Messrs. Doulton's).

Composition per cent.:—

—	Common White.	Best White.	"Pike."	Top Brown for Chemical Apparatus.	Best Brown.	Yellow.
Water - - -	8·01	2·81	3·23	2·05	—	6·19
Sulphur trioxide - -	0·62	0·58	0·10	0·30	0·15	0·12
Equal to sulphur -	0·25	0·23	0·04	0·12	0·06	0·05

THE "SALTING" PROCESS.

The furnaces generally take about five days firing before they are at a sufficient temperature (white heat) for salting. During this time the lower (furnace) holes are partially open, the upper ones, in the dome, almost entirely so, thus causing a rapid draught. The ware in the "fancy" kilns, 20 and 21, is coloured with various metallic pigments containing cobalt, manganese, &c., that in the chemical kilns is coloured generally with a mixture containing manganese oxide. Iron is also often present. Kilns Nos. 21 and 20 are small, used for "fancy" or artistic ware, and are fed with East Wylam coal. The larger kilns, Nos. 6, 7, &c. are used for "chemical" or "acid" ware, and consume Tunstall coal. During the heating a variable but generally small amount of soot with sulphurous fumes is continually evolved, the soot of course greatly increasing at time of coaling. When sufficiently hot, just before salting, the smoke is almost invisible. The fire is now urged, and salt

is thrown in below at each of the furnace holes in rotation, the operation lasting about five minutes. Copious white and pungent vapours now escape, but soon subside. In about 20 minutes from the time of commencing to salt the lower holes, these are almost entirely stopped, and each of the upper holes has a quantity of salt thrown in from above, about a bushel of salt being used. A tremendous crackling ensues, the decrepitation causing the particles of salt to be split up by the heat into minute dust, much of which is carried off unaltered by the draught, whence ensues not only waste, but the necessity for employing an excess of salt, and thereby creating a superfluous amount of fume. Possibly this might be avoided or lessened by previously pounding and drying the salt, perhaps on the dome of the kiln or in any sufficiently heated position.

The upper part of the kiln is now filled with white clouds of extreme pungency, acid and metallic to taste: the flame becomes strongly yellow from the presence of sodium. Below, the salt is converted into vapour by the intense heat, is then decomposed by the silica of the ware, forming silicate of soda or "salt glaze" over its surface, while hydrochloric acid is liberated and escapes with the excess of salt and the products of combustion of the coal.

The salting of the upper holes lasts on an average 12 minutes. In half an hour the salt fumes have much lessened; within an hour they have almost entirely disappeared. After salting the draught is cut off to a minimum, and the furnace gradually cools. On the interior of the outer dome a deposit of soot and salt accumulates to a depth of about half an inch. This contains hardly any free acid. Any surface exposed to the fume becomes crusted with an inconstant amount of salt, but the acid does not deposit to the same extent, being carried off by the vapours. The acid is also not very readily taken up by a surface moistened with water. Porcelain or iron placed in the flame from the upper holes gathers a considerable crust of fused salt. The interior of the lower (furnace) dome and the exit holes are coated with a thick saline glaze.

The amount of salt in the fumes rapidly diminishes after salting. The following are illustrative experiments :—

Bottles filled with sand and emptied in the fume; January 3rd 1879; at intervals.

No.	Time (Upper Holes).	Salt Incrustation.	Salt in Grains per Gallon of Gas.	Acidity.
1	At first salting - -	White, copious - -	3·76	Inappreciable.
2	Short time after - -	Not so abundant - -	2·40	Faint.
3	Ten minutes later - -	Hardly visible - -	0·37	Very faint.
4	Later - - - -	None - - -	0·07	Just distinct.
5	Three hours after - -	None - - -	0·02	Very faint.
6	Four hours after - -	None - -	0·02	Ditto.

On the same day some bottles were collected at the top of the chimney where the mixed fumes from all the holes issued into the air :—

No.	Odour.	Incrustation.	Salt (per Gallon of Gas).	Acidity.	Remarks.
			Grains.		
1	Slight - -	Few colourless crystals.	0·072	Slight - -	A little moisture.
2	Earthy and smoky.	Colourless crystals	0·156	Ditto - -	Grey fumes, moisture and soot.
3	Smoky -	A few colourless crystals.	0·120	·045 grains per gallon, calculated as hydrochloric acid.	More acid than the rest. No visible soot. An exceptional quantity of moisture.

These three specimens were taken some hours after salting. They show the influence of moisture on the deposition of acid and salt.

In the specimens collected below, the heat was too great for any steam to condense, and the resulting deposit was proportionately less at the same period.

At the manholes on the morning of the same day, soon after salting, seven cloths of five square feet each, wetted with distilled water, were held in the fumes. They became sooty, some quite black. The liquid squeezed out was sooty and smelt of smoke; it was faintly acid. After filtration it was brownish, and left on evaporation a brown amorphous residue with some crystals neutral to test paper, partially redissolving in water (a little tarry matter), blackened strongly with disagreeable pungent odour on ignition, ash white, soluble without effervescence in hydrochloric acid, distinct trace of iron, much sodium chloride, a little sulphate, lime inappreciable. The tarry matter and salt are the main constituents.

Afternoon of same day. Cloths moistened with distilled water were held for two minutes in the mixture of smoke and salt fumes at the top of the chimney about three hours after salting kiln No. 21. Results in the following table :—

No.	Surface in sq. ft.	Salt in Grains.	Ditto in Grains per sq. ft.	Acidity.	Sulphur Trioxide.	Remarks.
1	5	1·81	0·36	Very feeble	—	Sooty, smoky odour.
2	10	2·88	0·29	Faint -	—	Ditto.
3	5	—	—	Ditto -	1·17 grains =0·23 grains per. sq. foot.	Sooty.

The insoluble matter was mainly soot; there was also tarry matter, a little iron, and a mere trace of silica.

The *liquid* contains no appreciable iron, no lead, no arsenic, a good deal of organic matter of tarry nature, no silica, much sodium chloride and sulphate.

Hence salt and sulphate of soda are easily thus deposited, but the free acid mainly escapes.

Experiments with Absorption Apparatus.

See Table p. 82.

The apparatus (Fig. 8) used on March 7th was a series of three vessels of glass filled with glass beads moistened with distilled water, and a fourth bottle with a shallow layer of distilled water. The inlet end of this system was

Fig. 8.

attached to a long tube (8 feet) of hard glass with a porcelain or platinum end, inserted well into the flame from one of the holes of the inner dome. The suction was effected by connecting the exit end with the top of an "aspirator," a large barrel filled with water; the water escaping from a tap below corresponded to the gas drawn through, and was measured in gallons. On March 14th and subsequent dates the apparatus was doubled (8 bottles); on May 9th it was quadrupled (16 bottles) to ensure more complete and rapid absorption. Even with the 16 absorbers the gas could only be drawn at the rate of a gallon in six minutes (which was the general speed), to be certain of complete absorption, indicated by the gas at its exit being tasteless and free from white fumes. The glass connecting tubes having an internal diameter of

0·2 inch, this would be a velocity of 13 feet per minute, or 2·6 inches per second. Owing, however, to the perfect mixing of the gases at the holes in the dome, the results are as fairly average as if an immensely larger apparatus, and a greater volume of gas were used for the experiment.

The first and second vessels generally became very sooty, and in a few of the trials a yellow waxy body appeared, which was further examined (page 90). After drawing, the liquid was washed out, made up to a definite volume, and analysed as at page 90.

The porcelain (furnace) end acquired a thick salt glaze with many brown spots. On the glass at the hot end a crust of salt collected, however fast the current of gas. A little moisture and much soot also collected at the cooler end of the tube.

The fumes were white or sooty, acidulous and metallic in taste, had a peculiar tarry and aromatic odour like the yellow body, and were exceedingly choking.

Some distilled water in which a large number of the beads had been soaked for seven days had taken up no lead, iron, or acidity.

Before using, the beads had been cleansed with a mixture of concentrated sulphuric and nitric acids, then washed with tap-water, and finally with distilled water till neutral.

The kilns examined were :—

A.—Nos. 20 and 21, small size, used for "fancy ware," with East Wylam coal, and

B.—Nos. 6 and 7, larger size, employed for "chemical or acid ware," with Tunstall coal.

The least amount of salt, "about a bushel at each salting," seemed to be used for No. 21, rather more with No. 20, and still more with Nos. 6. and 7; 20 and 21 were usually salted in the daytime, 6 and 7 at night or early morning. Copious white clouds, yet not nearly so dense as at a neighbouring pottery, were emitted from the chimney during salting; they soon lessened, and finally became almost invisible. Even then, however, they were sulphurous and pungent.

The results of the analyses are given in the table, the quantities being stated in grains per gallon of gas drawn. A general idea of the indications may be drawn from the following average figures for No. 21 kiln :—

Time.	Total Solids.	Mineral Matter. (Ash.)	Salt.	Volatile Hydrochloric Acid.	Total Acidity. *	Sulphur Trioxide. †	Sulphur Dioxide. ‡	Metals (Lead and Iron).
Salting of lower (furnace) holes.	·357	·287	·193	·034	·085	·014	·026	Absent.
Salting of upper holes.	·218	·183	·076	·066	·086	·042	·024	Generally a trace of both metals.
After salting, when main fumes ended.	·137	·120	·012	·021	·028	·074	(?) ·043	Lead absent; iron nearly absent.

* Calculated as hydrochloric acid; including sulphurous acid, &c.

† Present as fixed salt, mainly sulphate of soda.

‡ The sulphur dioxide (sulphurous acid) is mostly free, as gas; in the last case (·043) it must be partially in some non-acid form, as a salt of ammonia or an organic sulphur-compound, as the total acidity (·028) is only a little in excess of the volatile hydrochloric acid (·021), some of which might also be present as ammonium chloride.

This table shows that :—

(*a*.) In salting the *lower holes*, more salt as such, and less hydrochloric acid are evolved, *i.e.*, most of the salt thrown in is ejected unaltered and not decomposed by the ware, and hence *does not afford a glaze*. Does not this suggest a doubt whether this part of the process be really necessary, and whether it do not merely increase the quantity of salt used and of fume evolved without corresponding advantage?

(*b*.) In salting the *upper holes* about equal quantities of salt (·076) and hydrochloric acid (·066) are given off, about half to two thirds the salt thrown in being used to create the glaze. This appears to point to a further reduction in the amount employed.

(*c*.) *After salting* the salt evolved much diminishes, the hydrochloric acid less rapidly, so that the latter becomes nearly double the former.

Could not a smaller quantity of salt be used over a somewhat longer period?

(*d*.) The sulphur compounds appear to rather increase from first to last, but this depending mainly on the firing, and, varying very much, may be considered somewhat doubtful.

The foregoing remarks may be rendered clearer by a reference to the chemistry of salting. The chloride of sodium, converted into vapour by the intense heat, is decomposed by the siliceous surface of the ware forming over it a fusible glaze of silicate of soda, while hydrochloric acid is liberated and escapes. The amount of the latter, therefore, furnishes an index of the quantity of salt really decomposed to produce the glaze.

In a drawing which lasted throughout the entire time of salting both upper and lower holes, till salt had almost entirely disappeared from the fumes (flame no longer *yellow* from sodium but *blue*),—time 73 minutes—the average amounts per gallon were:—Salt, ·103; hydrochloric acid, ·068 grains, showing that about half the salt is ejected unused.

1. As to the difference between the kilns:—
   - (*a*.) No. 21 has in its fumes the least quantity of salt, of free hydrochloric acid, and of sulphuric acid, both during and after salting.
   - (*b*.) No. 20 evolves as much as the larger kilns.
   - (*c*.) The vapours of Nos. 6 and 7 are practically free from lead, but contain a distinct quantity of iron.
   - (*d*.) In 20 and 21 the surface of the ware is coloured with various metallic pigments (iron, cobalt, manganese, &c.) in small quantities; in 6 and 7 a heavier colouring (brown), containing manganese oxide, is used.
2. The lead and almost all the iron disappear soon after salting.
3. The relation of the sulphurous to the sulphuric acid is variable, sometimes the one, sometimes the other, predominating. This seems to depend on the amount of *iron* present. Both are invariably found.
4. No *arsenic* could be detected and no *copper*.
5. A good deal of tarry matter and a varying amount of soot accompany the fumes.
6. The evolution from different holes of the same furnace is very unequal, the centre hole always emits the most.
7. Though averages may be obtained, the individual experiments showed great irregularities at different times in all constituents.
8. *Sulphur* is derived from the coals, coke and salt. Although it is improbable that more than a mere trace can be attributed to the clays, yet it must be remembered that *even the sulphates* may be decomposed by the silica at so high a temperature, and the acid evolved in the gas. It would then secondarily attack the chloride of sodium (salt), forming sulphate of soda and hydrochloric acid, both of which pass off.
9. The salt and combined sulphuric acid, being solids, are pretty easily condensed; the sulphurous and hydrochloric acid with greater difficulty.

Amount of Hydrochloric Acid evolved.

A bushel (8 gallons) of salt is used at each salting. This salt, taken as it is without pressing down, has about the same specific gravity as water (6 ounces weight occupied the volume of $6\frac{1}{2}$ ounces of water). Hence a bushel of salt will weigh about 80 lbs. If we take the numbers ·076 of salt and ·066 of hydrochloric acid (the average, in grains per gallon, of 12 experiments during salting kiln No. 21), this will give us 43 lbs. of salt and 37 lbs. of acid as the proportions evolved.

Specific gravity of hydrochloric acid gas (air = 1) = 1·26.

Weight of a cubic foot of this at 60° F. = 672 grains.

Hence 37 lbs. (259,000 grains) would occupy a space at 60° F. of 385 *cubic feet, or* 2,406 *gallons.*

1 grain of this gas occupies $2\frac{1}{2}$ cubic inches. ·066 grn. = ·165 cub. in.

[1 gallon = 277 cubic inches.]

$$277 : 100 :: \cdot 165 : x = 0 \cdot 06.$$

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Hence the free hydrochloric acid is 0·06 °/。, by volume, of the escaping gas, or 1 volume in 1660·06 volumes.

It follows that the 2,406 gallons of this gas would be diffused through 1,660 times their bulk of air, &c.; this amounts to 3,993,960 *gallons*, or 639,100 *cubic feet*. Thus if the whole of the salt used were either volatilized or decomposed,* nearly 4,000,000 *gallons* of air, or 640,000 *cubic feet*, would escape into the atmosphere from the beginning to the end of the salting of No. 21 kiln.

The Process of Analysis.

I. An aliquot part of the liquid from the absorbers evaporated and dried at 100° C gave the "*solids*"; burnt below a red heat it gave the "*ash*"; this dissolved and titrated with silver nitrate gave "*salt.*"

II. A fresh portion titrated without evaporation gave total chlorides; deducting the actual salt and calculating, we obtain "*volatile hydrochloric acid.*"

III. "*Total acidity*" by standard alkaline solution and litmus. Point rather indefinite. Calculated as hydrochloric acid it is generally in excess of the "volatile hydrochloric acid." The latter may include ammonium chloride as well as the free acid. The "acidity" includes also the sulphurous acid, any organic acid bodies (?) &c. There can hardly be free *sulphuric acid* in any case, as an excess of salt is always present.

IV. For "*Sulphur trioxide,*" SO_3 (anhydrous sulphuric acid), a little hydrochloric acid and a few drops of pure sodium bicarbonate were added, the whole evaporated to dryness, re-dissolved, acidified and precipitated by chloride of barium.

V. "*Sulphur dioxide*" SO_2 (sulphurous acid). Oxidised by bromine water and precipitated by barium chloride, the sulphuric deducted, and the rest calculated as sulphurous acid.

VI. About 15 cubic centimetres tested with sulphuretted hydrogen for *lead*. About the same tested with sulphocyanide for *ferric or peroxidized iron*, then with pure chlorine water for *ferrous or protoxide*. Or, in some cases, with ferro-cyanide and ferri-cyanide in the usual way.

"Yellow Body."

Obtained only in experiments III., IV., and VIII., *see* table. Bright orange yellow, easily crumbling, odour aromatic; insoluble in water, floating on it without being wetted. Easily soluble in alcohol; very easily in benzol, chloroform, bisulphide of carbon; much less in ether; crystallising from solution in long thin needles. Sublimable at a high temperature in microscopic needles.

Appears to be allied to, or identical with, the hydrocarbons pyrene and chrysene, obtained from coal-tar, &c. It is evidently derived from the coal-smoke.

It burnt with a bright smoky flame, leaving a little ash.

LIME BURNING.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Dec. 6, 1876 -	Charles Tennant & Co.	Hebburn -	Manufacture of alkali, &c.
Feb. 5, 1877	Small Lime Kilns	St. George, Bristol.	—
June 5, 1878 -	Loan Head Oil Works.	Straiton, Edinburgh.	Distillation of shale.
Nov. 19, ,, -	Burham Cement Works.	Burham, near Maidstone.	Cement making.

* Some escapes, gathering on the edges, or falling below.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Mar. 3, 1879 -	Mond - -	Northwich -	Manufacture of alkali by ammonia process.
April 2, „ -	E. Breffit -	Castleford -	Manufacture of glass.
„ 6, „ -	P. W. Spencer -	Lothersdale, Skipton.	—
May 7, „ -	J. Ellis and Sons	Sileby, Leicestershire.	—
June 5, „ -	Gaslight and Coke Company.	Beckton -	Gas making, &c.
„ 14, „ -	Buxton Lime Co.	Burbage, Buxton	—
„ „ „ -	Buxton Grin Works	Harper, ditto.	—
July 3, „ -	Stanhope Lime Works.	Stanhope, Durham.	—

Various methods of lime burning.

So far as I have been able to learn, the above-mentioned works have furnished me with illustrations of the various modes of burning lime which are in use in this country. The material burned is either chalk or some variety of limestone; at one of the above-mentioned works alone I found a carboniferous limestone in use. Lime is burned, similarly to bricks, in either open or closed kilns, and either coal or coke is generally in use as the fuel. At one work only, namely, at a small work near Bristol, did I find breeze (cinders) gathered out of town refuse used as the fuel. The feeding in of material and fuel may be intermittent, each charge being burned and drawn before a new charge is introduced; or the feeding and drawing may be continuous, in which case the material and fuel are fed in at the top, as space is afforded by the drawing of burned lime at the bottom of the kiln. The former method of burning is most in use with closed kilns, and the latter is most in use where the kilns are open.

Open kilns.

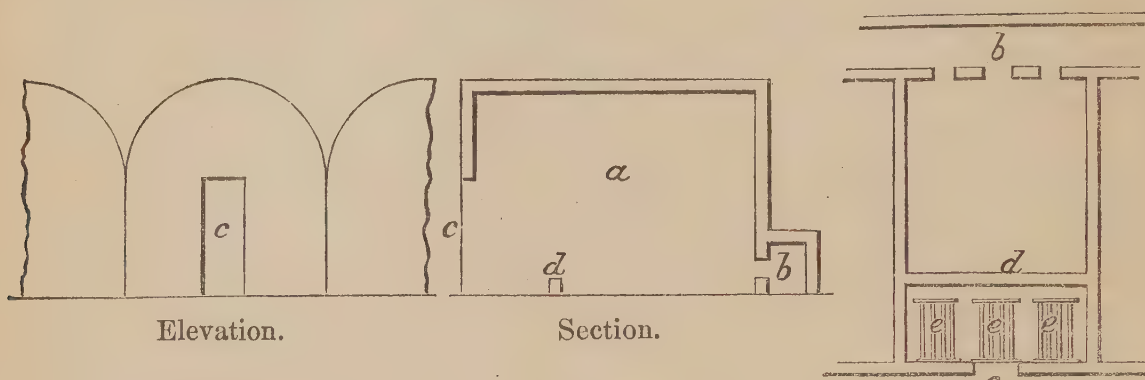
The ordinary form of an open lime kiln is that of a deep pit, narrowing towards the bottom, and lined with some refractory stone or with fire-brick; and at the bottom on one side there is a shoot or opening through which the burned lime is discharged. The exterior is built square with stone, and where a pair of such pits are placed side by side the discharge is effected into an arched passage constructed between them below. Such a kiln is worked on the continuous system, alternate layers of limestone or chalk and fuel being charged in. Another kind of open kiln used at Sileby for burning lias limestone is a pit which is not deep: after the pit has been filled, more limestone and fuel are laid on the top so as to form a conical heap, which is finally covered with a layer of earth patted down upon its surface. This kiln is worked on the intermittent system.

Closed kilns.

The closed kilns I have seen in use are similar to some of the closed kilns used for brick-burning. One of these forms much used in the glass-making districts of the north of England, is the "Newcastle kiln," as I have heard it called. It consists of an arched chamber, Fig. 9, *a*, having communications behind at the lower part with a flue *b*, and having an opening or doorway *c* in front, which during burning is bricked up. The front part is marked off from the rest of the floor by a low brick ridge *d*, behind which the limestone is built up, yet so as to leave near the floor passages about 18 inches high from the ridge to within about 3 feet of the back wall of the kiln. The fire is sometimes placed on the floor in front of the ridge, and small air-openings are left in the bricked-up doorway; but in other cases fires are kindled over fire-bars *e* with ashpits beneath, in the situation shown in the plan: in either case

there are openings provided for the feeding in of fuel. The smoke passes into the flue, and is conducted by it from all the kilns in a series to a chimney. This kiln is worked intermittently. Another form of close kiln is essentially an ordinary open kiln covered or domed in at the

Fig. 9.



Plan.

top, having an opening near the top which conducts smoke, &c. into a flue. At Mond's works, where coke is used as fuel, the carbonic acid generated from the combustion is carried into the works by a pipe, and used in the manufacture of carbonate of soda.

Hofmann kiln. At the Harper Works of the Buxton Lime Company a Hofmann kiln is used. It is of similar construction to that described as in use for brick-burning, except that there are openings to the flues both on the outer and inner side of each compartment. It has 28 chambers, which are worked, in sets of 14, round and round the kiln. Mr. Jacob Hill, the manager, informed me that the time occupied in working round the kiln in this way (and therefore the time between charging and discharging each compartment) is from 14 to 25 days, equally good lime being made in any case, whether the kiln be worked quickly or slowly. At my visit I found, in each set of 14 compartments, nine doorways bricked up and five open; the middle compartments of the nine were in a state of active ignition, and two at the end of the set were burned out. The iron partition was *in situ* at the end of the set. Beyond the partition were open compartments in which the stone was being built up.

Nuisance; The nuisance proceeding from lime-burning is chiefly that of the smoke which issues from the kiln at a low level. The coal burns in a smouldering way, and gives rise to more offensive products than when it burns freely. That which comes off from a row of large kilns is sometimes very abundant, and clouds the air for a very long distance as it floats away near the ground. No smoke and very little obvious vapour, beside watery vapour, arise from kilns in which coke is used, unless the coke has a little small coal mixed with it, or when some coal is used towards evening to keep the kiln going during the night. In the solitary instance in which cinders were used, with which organic (chiefly vegetable) refuse was mixed, the effluvia were very offensive, the odour being similar to that arising from the clamp burning of bricks about London. The burning of carboniferous limestone gives rise to a particularly offensive fume, due to the evolution of similar products to those which are obtained by the distillation of oil-shales.

Injury to health. The gases given off from a burning lime kiln are poisonous, and may injure the health of persons residing near, if they chance to enter the house in any considerable quantity. Mr. J. B. Hannay, F.R.S.E., of Glasgow, has given me an account of his own sufferings from this cause when, being manager of some lime works, he resided in a house distant about 150 yards to the west of the kilns, the ground having a gentle slope from the kilns to the house. He attributed his sufferings to

poisoning with carbonic oxide. He says, "After living there for some "time I began to notice that I was extremely sensitive to the east "wind, losing appetite and especially memory, and feeling altogether "miserable, especially if the wind lasted some days and did not blow "strongly. I used to long for a west wind as a panacea for my troubles, "which at first were only low spirits, want of appetite, weakness of "thinking power, and loss of memory. I used to notice, too, that I "would sleep much longer than was customary to me, often nine hours, "and never dream, but sleep a dead sleep. As time went on, my "housekeeper became ill, suffering from headaches and general debility; "and she had to leave me in consequence. When she first came to "me she was exceptionally strong in health, having never been ill "before. My own constitution was very strong. My sister, who was "staying with me also became very ill; but want of sleep and head-"aches were what she chiefly suffered from. After a time all my senses "became painfully acute, and although I had a good deal of walking to "do, I became so weak that a walk of one mile wearied me out. At "first my symptoms of illness used to disappear with the occurrence of "a west wind, but they at once returned with an east wind or a calm. "When I had resided at my house about 2½ years I became so ill "after a spell of east wind that, although not confined to bed, I could "do no work, and therefore started for the Mediterranean. When, after "six days, I arrived at Lisbon, I felt nearly well again, and before I "left Gibraltar to go to Italy I had regained my usual health. When "I left Glasgow at the end of February, I weighed only 9 stone 10 lbs. "(a mere 'bag of bones'), and when I returned in May I weighed "11 stone 13 lbs. My height is 5 ft. 10 in. I may add that the "carbonic oxide in the atmosphere of my house was in sufficient "quantity to be tested for chemically. Although its operation was "upon the nervous system, lowering vital power altogether, it acted "somewhat differently from over-work (of the effects of which I have "also had a taste), since, when I was nearly idle, I became ill imme-"diately an east wind occurred. The foreman of the carters had a "small house near mine, but slightly off the line from the kilns, and his "wife and family were martyrs to head-ache, and nervous weakness, "although when they were away from home they enjoyed good health. "It appears that if a man be actively employed and moving about all "day, and especially if he sleeps in pure air, the gases have very little "effect on him. When I was away all day and slept at night in the "impure air I was unwell, but if I slept away from the works I never "felt the bad effect, although I must have breathed the gases during the "day."

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Sources of nuisance.

Since the greater part of the nuisance of lime burning is due to the products of the imperfect or slow combustion of the fuel used, one obvious mode of lessening the nuisance is so to burn as to use as small a quantity of the fuel as is practicable for the attainment of a good result, or to use such fuel as does not emit offensive smoke. The use of such offensive matter as I saw in use at Bristol is inexcusable. At most of the large lime works in Derbyshire the fuel used is the commonest and cheapest coal that is obtainable. Some I saw in use was very largely indeed mixed with shaly matter ("bass"), and the quantity therefore thrown into the kiln with the stone was enormous. The bad quality of the coal necessitated this extravagant use of it, and the result of the burning was commensurably bad. A good deal of the stone introduced was discharged imperfectly burned, and mixed with the lime drawn were clinkers and stony matters, and the lime had to be picked over by hand. Thus two products were obtained, namely, lime and

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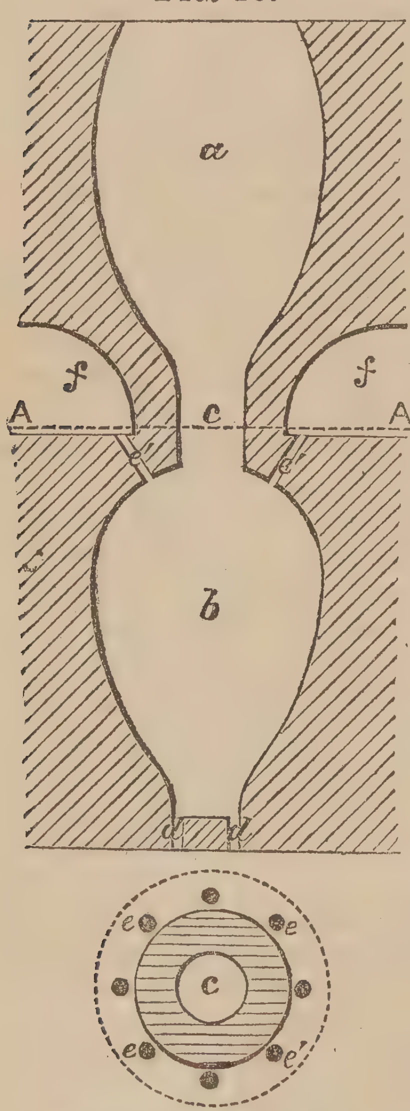
Prevention of nuisance.

refuse matter, both of which had to be carted away separately. The refuse made may be seen forming large heaps or mounds in the neighbourhood of any of these works. Such a mode of burning is not only a source of nuisance but is obviously wasteful of stone, time, and labour.

Precisely the same kind of stone which is burned at the Grin works at Burbage, I saw being burned in the Hofmann kiln at Harper with the evolution of scarcely any perceptible smoke, and with the use of no more (I was informed by Mr. Hill) than three or four cwt. of coal to each ton of lime made, while the proportion of refuse picked from the lime was most insignificant. I could not avoid contrasting this with the result of the ordinary burning at a neighbouring work, when nearly as much refuse as of good lime was being carted away. Good Bakewell slack was being used at the Hofmann kiln.

I have only further to mention a form of kiln invented and patented by Mr. P. W. Spencer, and which is in use at his works at Lothersdale, where it is doing good work with but little evolution of smoke and with great economy of coal. Fig. 10 shows the principle on which the kiln is constructed. The kiln is made in two chambers *a b*, one above the other, with a sufficiently wide communication *c* between them. The limestone is charged in at the top of the upper chamber, and good slack is introduced at small openings or channels *e*, round the top of the lower chamber, access to these apertures being had by passages *f* constructed in this situation and between adjoining kilns. The feeding of limestone is continuous, and the lime is drawn as usual below at *d*. In this way the combustion of the fuel is caused to take place where it will produce the maximum effect, and the waste heat warms up the stone in the upper chamber before it falls into the lower chamber, where it is burned. Such a kiln is best constructed on the side of a hill for convenience of supplying the limestone at the top and drawing the lime at the bottom.

FIG. 10.



At the Loan Head works, the manager, Mr. Young, had fitted to one of his kilns, which was partially closed at the top, an arrangement for collecting and condensing the oils, &c. which came off during the burning of the carboniferous limestone. It consisted in a pipe or flue leading to a chimney, the draught of which drew off the vapours from the kiln. In the course of the pipe he had placed a continuous condenser similar to that in use at the oil works, and had succeeded in condensing some at least of the offensive matters; the condensed oils in this case have a marketable value.

Where ordinary close kilns, such as the Newcastle kiln, are used, the smoke and vapours may be conducted to a chimney which will discharge them at such an elevation as to prevent their becoming a nuisance.

MANUFACTURE OF COKE AND BREEZE.—IGNITION OF SPOIL-BANKS.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Mar. 16, 1878	Executors of Col. Hargreaves.	Wood Top, Burnley	Colliery.
June 19, „	W. Baird & Co. -	Glasgow.	—
Jan. 9, 1879	Ynys Tin Plate Works.	Clydach, Swansea	Tin plate manufacture.
„ „ „	Cwm Filin Tin Plate Works.	Swansea - -	Ditto.
„ „ „	Cwm Brwla Tin Plate Works.	Ditto - -	Ditto.
„ 14, „	Dowlais Iron Works	Dowlais - -	Smelting, &c. of iron.
„ 15, „	Tredegar Iron Works.	Tredegar - -	Ditto, and colliery.
„ „ „	Ebbw Vale Iron Works.	Ebbw Vale -	Ditto, ditto.
„ 16 „	Glamorganshire Coal Company.	Llwnpia, Rhonda Valley.	Colliery.
„ „ „	Forest Iron Works	Treforest, Pontypridd.	Smelting of iron.
„ 17, „	Blaenavon Iron Works.	Blaenavon -	Ditto, and calcining iron ore.
„ 18, „	Crawshay -	Cinderford -	Ditto.
„ 22, „	Jones and Son -	Windmill End, Dudley.	Colliery.
„ „ „	Pearson - -	Ditto - -	Smelting of iron and calcining "tap-cinder."
„ „ „	Moses Hill -	Ditto.	—
„ „ „	Various breeze ovens.	About Dudley, Old Hill, Darley End, &c.	Collieries.
Mar. 5, „	Stanier & Co. -	Silverdale, Staffordshire.	Iron smelting and calcining iron stone and "tap-cinder."
April 5, „	Darfield Main Colliery.	Darfield, Barnsley	Collieries.
„ „ „	Silkstone and Dodworth Coal Company.	Dodworth, Barnsley	Ditto.
„ „ „	Pindar Oak Colliery	Barnsley - -	Ditto.
„ „ „	New Oak Colliery	Ditto - -	Ditto.
„ 8, „	West Yorkshire Iron and Coal Company.	Ardsley, near Leeds	Smelting of iron.
June 19, 1879	Framwellgate Coal Company -	Durham - -	Colliery.
„ „ „	Bear Park, Branspeth Coal and Coke Company -	Ditto - -	Ditto.
„ „ „	North Branspeth Coal Company -	Littleburn, Durham	Ditto.
„ „ „	Browney Colliery (Bell Brothers)	Durham - -	Ditto.
„ 20, „	Newfield Colliery -	Willington, Durham	Ditto.
„ „ „	Four Establishments - -	Crook, „	Ditto.
„ „ „	West Thornley -	Tow Law, „	Ditto.
„ „ „	Brandon - -	Brandon, „	Ditto.
—	Other coking works	At various places.	—
—	Various cement works.	Ditto - -	Manufacture of cement.

Coke and "breeze."

The term "coke" requires no definition, everybody being familiar with the substance: the term "breeze" is equivalent to the term "cinders" as understood in London; it is lighter, looser, and mostly in smaller pieces than coke as commonly met with and sold. Coke-dust and the small broken coke seen in heaps at gasworks are sometimes termed "breeze"; but this is not what is meant by the term as I am now using it. Both coke and breeze are solid residues of the distillation or incomplete combustion of coal, and they vary in appearance and quality with the mode in which the distillation or combustion is effected, and with the nature of the coal employed.

Coal.

Coal as it lies in the coal-measures is interstratified with shale of various kinds, which is raised with the coal from the pits, and deposited near the pit's mouth, often forming at last huge heaps in this situation. These heaps are commonly called "spoil banks." The coal raised is more or less mixed with shale, while the shale contains in its substance more or less coaly matter which renders it to some extent combustible. Coal also contains more or less sulphur in the form of bisulphide of iron or pyrites, often plainly visible in it from its yellow colour and metallic lustre. Coals are classified as follows:—1. Lignite, an intermediate condition between peat and non-caking bituminous coal; 2. Bituminous or flaming coal, which burns in an ordinary fire-place with a more or less smoky flame, and leaves a solid coke when heated to redness in a close vessel; 3. Cannel, which is a bituminous coal rich in disposable hydrogen, burns without melting, and gives a copious bright flame; and 4. Anthracite, which is of a deep black colour, and when in powder has a bronze-like or sub-metallic lustre, is conchoidal in fracture, and does not soil the fingers. Of these various kinds of coal the bituminous variety is alone applicable to the manufacture of coke or breeze. Bituminous coal is classified into "caking" and "non-caking" coal. Dr. Percy ("Metallurgy"—"Fuel," 1875, p. 309), says that "in "some instances the caking of a coal depends on the manner in which it "is heated and the degree of heat to which it is subjected," and instances the non-caking coal of South Staffordshire, which, he says, if rapidly exposed to a high temperature such as a bright red heat in a close vessel, furnishes a pretty solid hard coke. The caking coals, however, are those which are preferred for coke making. Non-caking coal does very well for making breeze such as is employed by the nailers and chain makers of South Staffordshire and the adjoining part of Worcestershire, and is largely used for this purpose in the neighbourhood of Dudley.

Classification of coal.

Sulphur in coal.

In the work above referred to (p. 322 et seq.) Dr. Percy gives tables showing the composition of many varieties of coal, and of the quantity of sulphur contained in them, a point which is of much importance in relation to this report. In eight varieties of British caking coal the sulphur ranged from 1·51 per cent. to 0·55 per cent., the mean of the eight varieties being 0·86 per cent. In 10 varieties of Staffordshire non-caking coal the sulphur ranged from 0·55 to 2·37 per cent.; a non-caking coal at St. Helens, Lancashire, gave 0·90 per cent., and the sulphur in three varieties of Scotch non-caking coal ranged from 0·63 to 1·23 per cent. In the four varieties of coal from Dowlais (which is called there "semi-bituminous") the sulphur ranged from 0·55 in the "upper four-feet coal" to 1·22 per cent. The mean quantity of sulphur in these 18 varieties of coal was 0·98 per cent. In another work* I find tables showing similar particulars elaborately worked out for the Admiralty by Dr. Lyon Playfair. In 37 varieties

* Chemistry: Theoretical, Practical, and Analytical. Published by Mackenzie, and edited by C. W. Vincent, of the Royal Institution. Vol. I. p. 542.

of Welsh coal the quantity of sulphur ranged from 0·09 to 5·07 per cent. in the Resolven coal, the mean being 1·43 per cent. In 18 varieties of Newcastle coals it ranged from 0·06 in Haswell Wallsend to 2·85 per cent. in Broomhill coal. In seven varieties of Derbyshire coal it ranged from 0·72 per cent. in the Stavely to 1·30 in the Loscoe soft coal, the mean being 1·01 per cent., and in 28 varieties of Lancashire coal it ranged from 0·52 in Haydock Little Delf to 3·04 in Moss Hall Pemberton, the mean being 1·43 per cent.

Composition of coke.

"Coke," says Dr. Percy (op. cit. p. 417) "consists essentially of " carbon and the fixed inorganic matter of the coal from which it has " been derived, but contains also hydrogen, nitrogen, and oxygen, and " sulphur in the state of sulphide of iron," and he gives as one illustration of its composition the following analysis of coke from the Dukinfield Colliery made in his laboratory by Mr. C. Tookey :—

Carbon - - - - -	85·84
Hydrogen - - - - -	0·52
Oxygen and Nitrogen - - -	1·38
Sulphur - - - - -	0·86
Ash - - - - -	11·40
	100·00

Half the sulphur in the original coal, or thereabouts, is found in the coke made from it ; the bisulphide of iron in the coal being converted into protosulphide by the burning off of one equivalent of the sulphur and the production of sulphurous acid. So that, inasmuch as the sulphur varies in quantity in the original coal, the quantity of sulphurous acid given off and of sulphur left in the coke will vary extensively. The following from Dr. Percy (op. cit. p. 419) is the general theory of "coking":—

Theory of coking.

" When a mass of coal is put into a common gas retort previously " heated to redness, it is obvious that the portion of it which first comes " in contact with the red-hot surface of the retort must be exposed to " the highest degree of heat, and that for some time afterwards the " temperature will continue proportionately lower towards the centre of " the mass; and when a large quantity of coal, say several tons, is thus " heated in a single chamber, a considerable period must elapse before " the whole mass can become heated to the same degree. Hence, " during that period, the destructive distillation of the coal in different " parts will be effected at different temperatures. But the nature of " the products of such distillation varies with the temperature: thus, " at a low temperature volatile substances rich in carbon are generated, " which at a higher temperature are decomposed with the deposition of " carbon. When, for example, olefiant gas, which is one of the pro- " ducts of the dry distillation of coal, is passed through a red-hot " porcelain tube, it is decomposed with the separation of carbon and the " formation of marsh gas. Now in heating a considerable mass of coal " in the manner described, the temperature towards the interior may be " low enough to generate various highly carbonaceous volatile products, " which, on approaching the walls of the chamber where the heat is " higher, will deposit a portion of their carbon; and it is in this manner " that the internal surface of gas-retorts acquires in the course of time " a solid and firmly adherent coating of carbon of considerable thickness. " Let us suppose coal piled to the thickness of two to three feet in a " fire-brick chamber, entirely closed with the exception of a hole in the " top to act as a chimney, and a few small openings through which air " from without may enter *above* the surface of the coal; and let us

"further suppose that the whole of the upper part of the coal is burning "actively, that air to sustain combustion is entering through the small "openings, and that the volatile products of combustion are escaping "through the hole in the top. The oven above the coal will speedily "be heated to redness, and the heat will be propagated downwards "through the coal, of which every portion will be successively subjected "to destructive distillation. The volatile products from below will "ascend through the redhot overlying stratum of caked coal, and pro- "tecting it from contact with atmospheric air, will prevent it from "burning to waste. But as these products have been formed at a much "lower temperature than that prevailing in the upper part of the oven, "they may be so rich in carbon as to be decomposed in their ascent and "deposit a portion of their carbon upon the coke which they traverse. "The deposited carbon is generally bright and almost metallic in lustre; "the coked coal will be coated with a deposit of this lustrous carbon, "while the more or less decarbonized residual gases will take fire as "they escape from the incandescent mass and come in contact with the "air, which enters through the small openings above the surface."

Process of manufacture of coke.

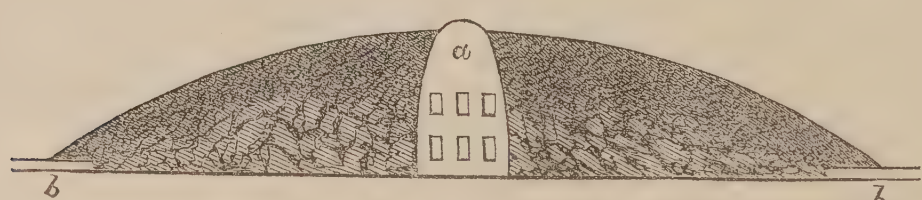
The manufacture of coke as one of the bye-products of gas-making will be described hereafter (p. 108). But while gas-coke is applicable to domestic use and to some manufacturing processes, such as cement making, it is not fitted for some other purposes, such for instance as iron smelting, and therefore coke for such purposes has to be specially prepared. The modes in which it is made are either by heating the coal with a restricted supply of air in heaps or "piles," or in what are termed "coke-ovens." These two methods must be separately described.

1. Coking in piles.

1. *Coking in piles.*—I saw this mode of coking pursued at Blaenavon and Cinderford. I am informed that it is a method which was more extensively used formerly than it is at present, since the coke produced is softer than the coke made in ovens, and less fitted for use in iron furnaces worked, as is commonly the case now, with the hot blast. For this mode of manufacture a flat space of ground is selected, and on it many piles are raised, which may be observed in various stages of the process at any one time. The heaps or piles are made either circular or in the form of an elongated bank, and are usually about 4 feet high in the middle. At Crawshay's works at Cinderford, each circular pile was about 8 yards in diameter, and coked about 20 tons of coal. At the Blaenavon Iron Works the elongated banks were of various lengths and about 10 feet wide at the base, from which they tapered up to a flat top, like a railway embankment.

Fig. 11 represents a section of one of the circular heaps above mentioned. There is in the centre a hollow permanent firebrick dome or

Fig. 11.



chimney *a*, which is provided with air openings, and around the base are inserted at the edge, and extending about 2 feet into the heap at regular intervals, 10 or 15 pieces of iron *b*, bent into the form of a channel, but inverted so as to form conduits for the admission of air to the base of the pile. In building up a pile, the largest blocks of coal are placed in the middle and at the base, smaller and smaller pieces being arranged outside these to the surface, which is closely covered and patted down with coke-dust. A hole is left near the dome, down

which fire is dropped to ignite the heap, which burns therefore from the centre towards the edges.

The elongated heaps at the Blaenavon Works were built up much in the same way; the largest pieces of coal were placed in the middle, and the small lumps at the edges were so arranged as to permit of the admission of air at this part. There was no central dome. The heaps were ignited at one end. The process of the coking is carefully watched, and whenever the workman considers the combustion too vigorous, he covers the part with fresh coke-dust to exclude the air. So long as yellow flame appears the combustion is allowed to go on, but a blue flame indicates the formation of carbonic oxide from oxidation of the carbon, which is not desired. The process is continued usually from five or six days, and then the whole pile is closely covered up with damped coke-dust, and left for the fire to die out, or the fire is extinguished with water.

2. Coking in ovens.

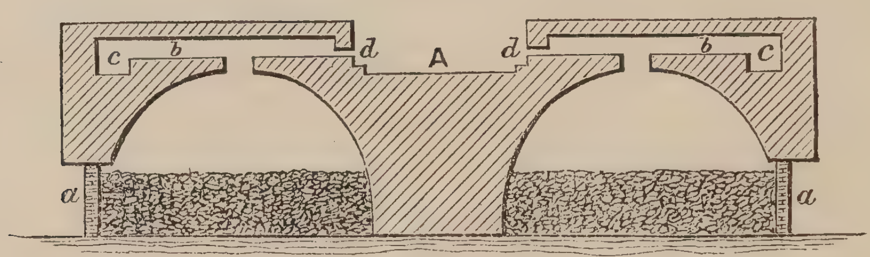
2. *Coking in ovens.*—This is the usual mode of coking. In the section on cement making I mentioned that coke was made in ovens, partly with a view to utilise the hot air proceeding from them for heating the slurry floors. Fig. 5, p. 63, represents the usual form of these coke ovens in longitudinal and transverse section, B being the charging opening which during coking is filled in with bricks or plastered over, one or more small openings being left near the bottom, C the slurry floor, and D and E flues beneath it.

Various forms of ovens.

"In its simplest form," says Dr. Percy (op. cit., p. 431), "a coke oven "is a flat-bottomed chamber, arch-roofed, made of fire-brick or other "refractory material, provided with two openings, one in the roof to "serve as an outlet for the volatile products of carbonisation and as an "inlet for introducing the coal, and the other in the circumference or "wall to serve as a doorway for withdrawing the coke." Such ovens pass under distinctive names in accordance with various minor modifications of form and arrangement. Thus there is the "bee-hive" oven (the ordinary form in Durham) of circular form, covered with a domed roof; the diameter of the floor varying from 8 to 11 feet, and the height of the dome in the centre varying from 5 to about 8 feet: and there is the "rectangular" oven, with an oblong floor, say 14 feet long and 6 or 7 feet wide (the dimensions varying however), and arched roof. Sometimes the oven is less than 5 feet high, and the floor is raised above the level of the ground outside. Coke ovens may stand separately or in pairs, side by side or back to back; but where coking is carried on to a large extent they are erected many together, side by side in a row, or two rows may be placed back to back, so as to form a block of 30 to 100 ovens, the doorways of one row being on one side of the block and those of the other row on the other side. On the summit of each row in these cases there commonly runs a tramway to carry slack in waggons for charging the ovens through their roofs. When it is intended to draw the coke in one block by machinery, as is done in the case of some rectangular ovens, the floor rises a little, and narrows a little also, towards the back of the oven. The doorway of a coke oven runs from the floor about half-way up the front of the oven, and its width varies, chiefly to correspond with the mode of drawing the coke adopted. When the coke is to be raked out, the width of the doorway is only from 2 to 3 feet; but when it is to be discharged in one block by a mechanical arrangement it extends the whole width of the front of the oven. During the process of coking this front opening is either bricked up or closed by an iron plate or door; or the door consists of a frame of iron in which bricks are laid, and is raised when requisite by means of a pulley and counterpoise. Beside the door there may be only the central

aperture or chimney in the roof; but commonly there is a flue proceeding from the back part of the oven, by which the products of the combustion are carried off, the central opening in the roof being only used for charging the oven. Where the oven is charged by the door, there may be no central opening in the roof. In all the old-fashioned coke-ovens the smoke and the products of combustion pass away by the openings in the roof, or by low chimneys into which the flue of either one or else two ovens discharge themselves. But in some ovens of more recent construction various modifications of the flue arrangements have been introduced. Some of these may be mentioned. At Burnley Wood Top, for instance, the arrangement adopted is that represented roughly in the subjoined diagram (Fig. 12) of a transverse section of back-to-back

Fig. 12.



ovens: the charging is effected by the doorways *a a*, which are subsequently bricked up; the products of combustion are carried by a short transverse flue *b b* from the central opening to a common flue for each row *c c*, which discharges into a chimney-shaft about 60 feet high at the end; *d d* are openings in the short flue made by leaving a brick out there to assist in creating a draught for the chimney. At Baird's coke ovens at Glasgow the principle is the same; but there is only one small flue in the situation A, receiving short flues from the back part of the ovens, and leading to a chimney about 30 feet high at the end of the block of ovens. At the Dowlais Iron Works an endeavour is made to utilise the waste heat by conducting a flue from the upper back part of the oven to a flue 2 feet wide and 2 feet 6 inches high, which makes a circuit beneath the floor of the oven. The ovens (rectangular) being arranged in rows back to back, the flues are so arranged that four ovens discharge their flues finally into one chimney, but a chimney with four divisions, one for each oven. I have seen a somewhat similar arrangement in other places. In what is known as Cox's oven, which is a chamber of the shape of an ordinary rectangular oven, arranged for drawing the charge *en masse*, there is below the arched roof a second brick arch, reaching from the back of the oven forwards to within about 2 feet of the front, where it terminates with a free edge, so that there is a space included between it and the true roof of the oven. The air for combustion when the door is closed enters at the back of the oven (a flue being provided to conduct it thither), and passes forwards, the products of combustion passing off between the arch and the roof to the chimney common to two such ovens, but having a separate division for each. Plans of this oven are given in Dr. Percy's work (op. cit., p. 436).

I will reserve for the present what has yet to be said about other ovens having a common main flue.

The admission of air to support the combustion within the oven is provided for usually by means of holes left in the door closing the front opening, but sometimes otherwise, as by air channels passing at the sides of the oven near the spring of the arch, and opening at several places into the oven.

At the Blaenavon Iron Works I was shown a set of 13 ovens worked with a weak blast of air introduced at the sides of the oven by openings near the spring of the arch. The air was heated by being made first to pass through a coil placed in the flue by which the products of combustion from the oven are conducted to a main flue for the block of ovens. This principle is the invention of Mr. H. Aitken, of Darrock, near Falkirk.

Charging the oven.

Coke ovens once set to work, are kept at work until it is necessary to stop them for repairs. As soon as possible, after a charge is drawn, and before the walls have had time to cool, the oven is re-charged with coal.

It is customary to use for coking in ovens what is technically termed "slack," that is to say, the dusty coal for which a sale is not so readily found as for lumps of coal. It is also customary, when the coke is to be used for iron furnaces, to wash the slack so as to remove from it shaly matter and some of the pyrites.

At Pearson's works near Dudley, Staffordshire, non-caking coal-slack was, at the time of my visit, being coked by mixing it first with pitch, previously ground by a roller mill, in the proportions of one part of pitch to two parts of slack.

The slack is usually charged into the oven either from the central opening in the roof, or by the doorway, to a depth of about 2 feet or 2 feet 6 inches, and is spread on the floor as uniformly as possible. The heat of the oven ignites the charge, the door is closed or bricked up, and the combustion is continued so long as flame is seen to issue from the mass. Smoke and flame issue from the opening in the roof, or, from the low chimneys which are provided with arrangements for partial or complete closure at the later stages of the operation. An ordinary charge is usually fit to be drawn in about 48 hours: hard coke requires 72 hours. The door is then opened, and the coke is raked out on to the ground in front, or, in the case of some rectangular ovens, the whole block of coke is, by a mechanical arrangement which I need not describe, drawn out in one coherent mass. Being in an ignited state it has to be quenched: this is effected by causing water to play upon it from a hose, either after it has been drawn or while it is yet lying in the oven.

Drawing the charge.

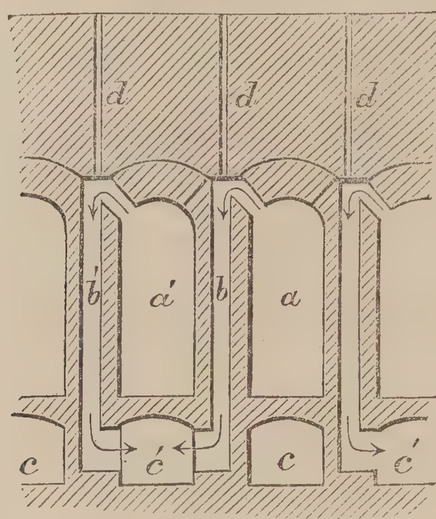
The Coppée oven.

The Coppée oven requires special description. I saw it in operation at the Ebbw Vale Works.

Dr. Percy in his work (op. cit., p. 545) gives a full description of this oven, with plates fully illustrating its construction; but the diagram Fig. 13 will suffice to illustrate its construction for the purposes of this Report. It consists of a series of long narrow arched chambers a a^1, set side by side in a block, and having an opening or doorway at each end, which doorways are closed by iron doors constructed in two parts, so that the upper part next the arch can be open while the lower part is closed. The chambers are slightly narrowed as they pass from one end towards the other end, in order to allow of the coke being readily pushed out by a steam ram, the piston of which is introduced at the narrower end. The coal is fed in by three openings at the top, one in the middle, the other two midway between the middle and the ends, and it is levelled by rakes introduced at the upper part of the doorways. The chambers are worked in pairs, and there may be any number of such pairs in one block. Fig. 13 represents one pair of these chambers worked together. It will be observed that there are passages b b' constructed in the thickness of the wall separating one chamber from another, which passages have upper openings into the left-hand side of the top of each chamber at the spring of the arch and, at their lower end,

enter a flue beneath one of the pair of chambers c'. The products of the distillation of the coal in a pass by the vertical passage b down to a

Fig. 13.



flue c', running from front to back horizontally beneath the whole length of the chamber a', and the products of the distillation from the chamber a' pass by the passage b' into the same flue. The flue c', on arriving at the further end, communicates by two openings or passages with the flue c, which passes forwards under the whole length of the chamber a, and on arriving at the end, communicates with a large common flue underground, which leads to the chimney stalk. Air for combustion of the gases is admitted by channels d into the top of the vertical passages b and b'. The admission of air is regulated by dampers. The ovens, although worked in pairs, are not charged simultaneously, "one oven of "each pair being charged when the contents of the other are half coked, "and *vice versâ*. Air is admitted to the volatile products evolved from "each oven, and then the products evolved from the two ovens forming "the pair are mixed; by this means the rich hydrocarbons, which are "generated at a comparatively low temperature at the commencement "of the operation of coking, are raised to a higher temperature by "admixture with the more highly heated products simultaneously "evolved from the other oven of the pair, and are, it is believed, "effectually burnt" (Percy, op. cit., p. 547).

Breeze-making.

"Breeze-making" in South Staffordshire is effected in two ways: either the non-caking coal of the district is burned in a heap on the ground (locally termed "hearth-coking"), or in ovens. By the first method a large heap of coal is lighted and allowed to burn away in great measure, and is then quenched with water. In the second method a circular oven standing alone, about 10 feet in diameter, is used. It consists of a floor raised about 2½ feet from the ground, and enclosed in a domed chamber which has a chimney opening in the centre and a square doorway on the level of the floor on one side. The process differs from coking in the free admission of air, the doorway being open during the whole time, and in the gradual charging of the oven. The first layer thrown on the floor having ceased to flare, another layer of coal is thrown on it through the doorway, and so on at intervals, the coal is thrown in layer upon layer, until an accumulation to the height of about 2½ feet has taken place on the floor. The whole charge is then drawn into barrows and wheeled away to a heap on the ground, where it is quenched with water, sifted by hand, and then washed by hand by throwing into a tub of water; the shaley matter sinks to the bottom and the breeze is skimmed off.

Nuisances from coking.

"Coking," as commonly carried on, is a very great nuisance, on account of the constant issue of large volumes of black smoke, which is, according to the character of the coal used, more or less charged with sulphurous acid. Issuing at a low level, the fume sweeps along with the wind close to the surface of the earth, and produces a sooty and acid condition of the atmosphere in the neighbourhood, which is distressing and suffocative to strangers, and the unwholesomeness of which, to persons habitually exposed to it, it would be an insult to common sense to question. The mere respiration habitually of such an atmosphere, by young children especially, and the obscuration of sunlight must be injurious ; but, in addition, an habitual disregard of wholesome ablution is sure to grow up out of the despair generated by unsuccessful efforts to maintain even an approach to personal or domestic cleanliness under such circumstances. Mr. Colquhoun, of the Tredegar Works, informed me also that, prior to the adoption of the improvements to be presently mentioned, the smoke and sulphurous fumes from their ovens used to be drawn with air into the passages of one of their coal mines when the wind was blowing in a particular direction, and vitiated the air required for ventilation. Another nuisance arises when the coke is quenched, sulphuretted hydrogen, in amount varying with the quantity of sulphur originally present in the coal, being given off with the steam created by the process.

From breeze-making.

In the neighbourhood of Dudley the breeze-ovens are the source of the greatest nuisance from smoke, which at each addition to the charge issues in black volumes both from the chimney and doorway. These ovens, for their size, produce more smoke at a low level than any other business carried on in the Black Country, and are thus a greater source of mere annoyance.

Mr. J. Lowthian Bell estimates that in addition to the smoke given off from the coke-ovens, no less than 60,000 or 80,000 tons of sulphurous acid are thrown annually into the air from the coke-ovens in the county of Durham alone ; and this not generally in the county, but in the various limited areas where this industry is carried on.

Modes of coking inoffensively.

When I saw the ovens at Dowlais (described at p. 100) at work, I thought that there was less smoke emitted than is usually emitted from coke-ovens of the ordinary construction. At the Ebbw Vale Works there was decidedly less smoke issuing from the Coppée ovens than is customary in coking. Part of the heat from these ovens is used at Ebbw Vale to heat the boilers which work the coal-washing machinery.

The Coppée oven.

Use of large flue.

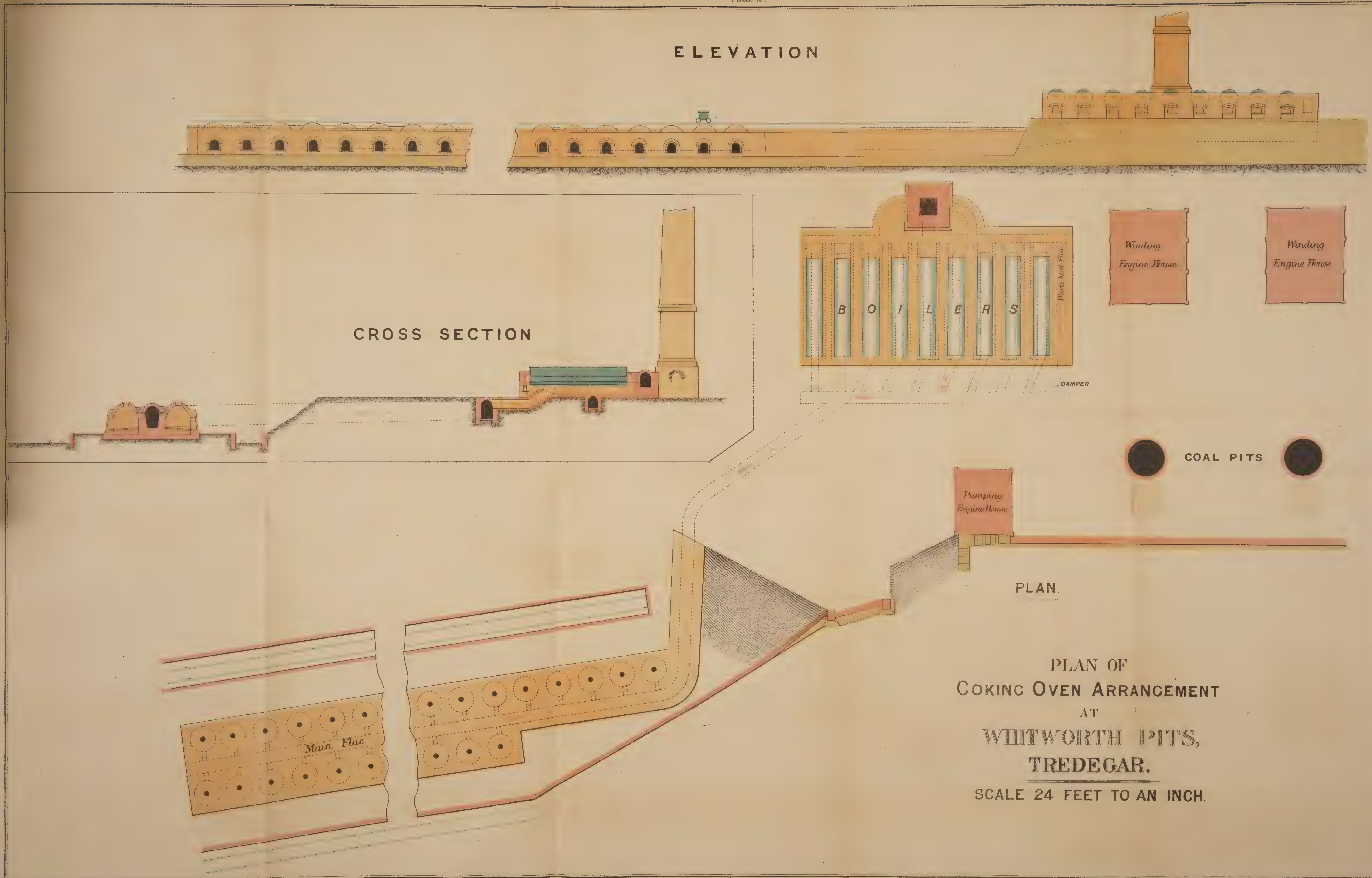
But practically the best arrangement for preventing the smoke nuisance was that which I saw in operation at the Browney Colliery, the Brandon New Colliery, and at the Tredegar Iron Works. There was absolutely less smoke sent into the atmosphere from a large number of coke-ovens at these works than customarily issues from the chimneys of an ordinary dwelling-house. Indeed the smoke issuing from the stacks at these works was scarcely perceptible. The ovens at the Whitworth and Tytrist Collieries, Tredegar Works, numbering 119, are of the bee-hive type, and are built in double rows, back to back, with a tramway on the top of each row. They are charged from the tramway through a small hole in the roof of each oven, which at other times is kept thoroughly closed. Between the rows of ovens, and running the same size all along the whole length of the block, is a capacious passage or main flue into which each oven discharges the smoke, &c. by means of a small connecting flue. The shape and dimensions (8 feet high, 5 feet wide at the spring of the arch, and 4 feet wide at the bottom) of this main flue are shown on the accompanying drawing, Plate X., obligingly prepared for me by Mr. Colquhoun, the manager, to whom I am also much indebted for his per-

APP. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

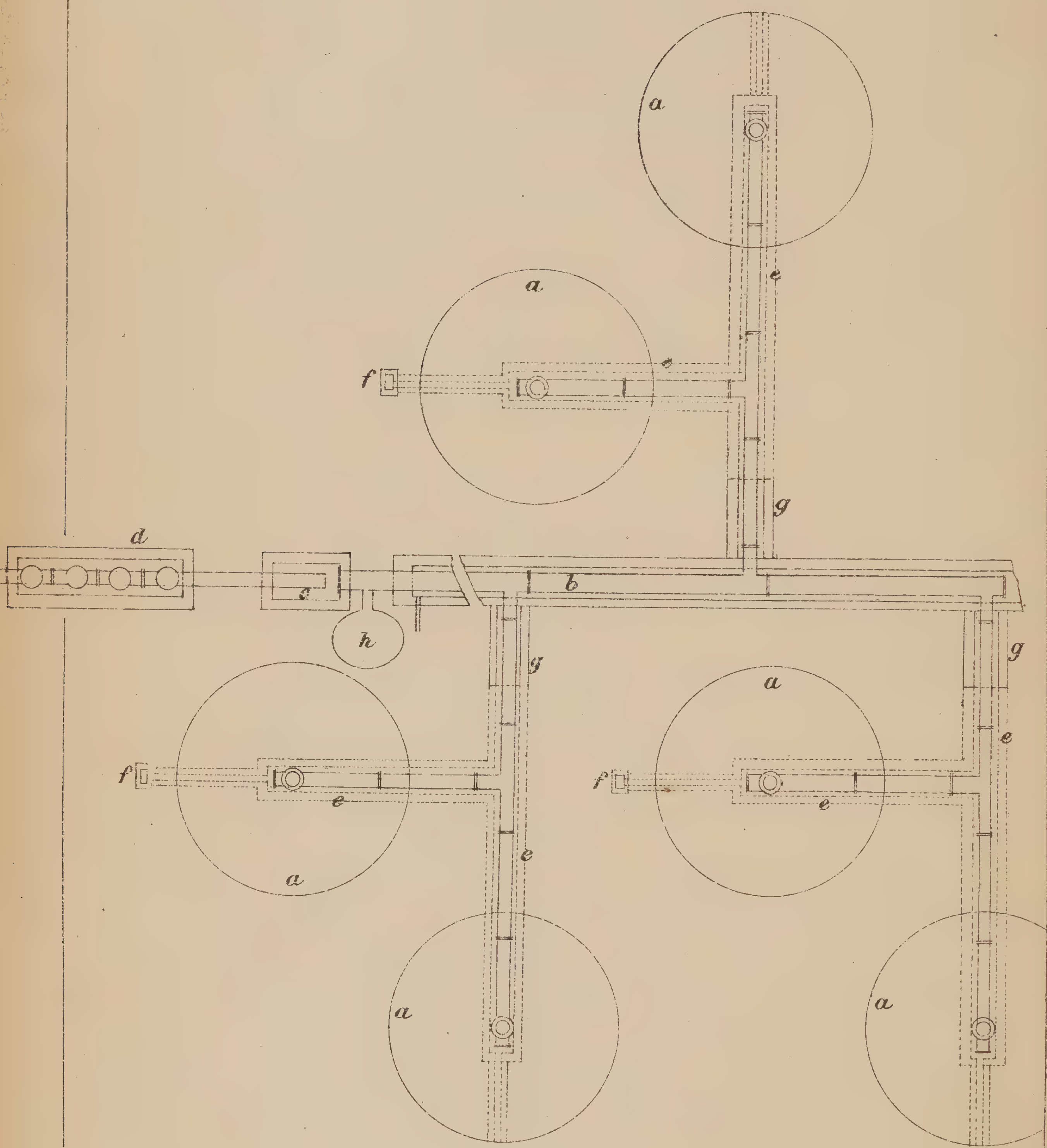
sonal attention and courtesy when I visited the works. The waste heat from the ovens raises the interior of this flue to a bright red heat, and passes from the flue to heat a series of boilers, beneath which it is conducted by branch flues, and is finally discharged into the atmosphere by chimney shafts 150 feet high. Each branch is provided with a damper for regulating the admission of the waste heat under each boiler. In Durham, a similar arrangement is adapted at the Browney Colliery to 338, and at the Brandon Colliery to 400 ovens. Two practical advantages of this arrangement lie in the facility it affords for the utilisation of the waste heat, and in its adaptability to existing blocks of ordinary beehive or rectangular ovens. The full force of the former of these advantages may not be appreciated at its first mention. Where the waste heat of the ovens is not utilised, separate fires have to be kept up to heat the boilers of the machinery that does the work of the pits and the coal-washing, and usually the smoke from the chimneys of these boiler furnaces is an additional and considerable source of nuisance. But when the waste heat from the ovens is utilised in the way pointed out, not only is the smoke nuisance from the ovens done away with, but also that from the boiler furnaces, and the atmosphere is left thus absolutely clear of smoke. An illustration of the latter advantage is to be seen at Tredegar, where a set of 32 old-fashioned rectangular ovens has been converted by building a flue between them, but at the expense of some little loss of space in the ovens. At the Treforest Iron Works this same arrangement has been adopted with modifications. There is here a block of 60 back-to-back beehive ovens, but the main flue is not constructed of the same size throughout. At the further end of the block the height is 4 feet, and the flue is 3 feet 6 inches broad at the spring of the arch, and 2 feet 3 inches at its floor ; at the end nearest the boiler it is 9 feet 6 inches high, 4 feet 6 inches wide at the spring of the arch, and 2 feet 6 inches at the floor. This large culvert leads to a chamber 21 feet long, 8 feet high, 8 feet wide, and this to a second similar chamber before the hot air reaches the boilers. At some other works which I have visited the flues are made smaller as they recede from the boiler end of the set. The Silkstone and Dodworth Coal Company have adopted the arrangement, the dimensions of the culvert being the same as the largest dimensions just mentioned. But here and at some other works the side walls have been built vertical, so that the flue is of the same width all through. Wherever this has been done, the side walls have, in about three years, been found to have bulged inwards so as to require repairs, unless where they have been supported by transverse pigeon-holed walls ; but even these walls are apt to break down, while their presence has appeared to me to lessen the draught. The large culvert has also been adopted for about 100 rectangular ovens by the Glamorganshire Coal Company at Llwnpia, where Mr. Archibald Hood is the manager. But here, in addition to the flue leading from the ovens to the culvert, each oven has a low chimney which is covered by a flagstone. There is a damper in the flue leading to the culvert, and when the coke is to be quenched, this damper is put down so as to cut off communication with the culvert, and the little chimney is opened by removal of the flagstone. I confess I see no great advantage in this arrangement, while it has this disadvantage, that the workmen do not always, after quenching the coke, restore the chimney cover, or do it so incompletely that smoke issues. At the time of my visit the effects of this negligence were making themselves visible. The culvert at these works is 6 feet high by 4 feet wide from the floor to the spring of the arch, that is to say, it was of the same width all the way up. It has been suggested that, in converting ordinary back-to-back ovens into this arrangement,

Errors in flue construction.



Dangerfield Lith 22 Bedford St Covent Garden

MR. E JONES' ARRANGEMENT FOR PREVENTING NUISANCE FROM COKING IN PILES.



Scale, 1/16 of an Inch to a Foot

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it might suffice to build the culvert on the top of the block between the rows so as not to encroach on the oven space. But it is open to objection. At several of the large coking works connected with collieries in the county of Durham and also in Yorkshire, I found that main flues had been erected on the tops of the sets to collect the smoke and conduct it to chimneys of heights varying from 40 to 100 feet and upwards. They were mostly old beehive ovens that had been thus flued. Each chimney usually received the smoke of about 30 ovens. The flues were often built so as to rest in part upon the tops of the ovens, and when this was the case I found frequently that the roof in this situation had broken down, the flue itself becoming fractured, and sometimes that the weight of the flue had pushed forwards irregularly the front part of the ovens. When such a break down happened, and repairs had consequently to be effected, the flue in the distant part of the set beyond this spot became ineffective, and the tops of the ovens being left open for the purpose of the draught, the old nuisance was re-created. The flues I am describing are usually about 2 feet 6 inches wide, and are constructed so as to taper away in height from about 5 feet near the chimney to about 2 feet 6 inches at the end furthest from it. The simple provision of a main flue, such as I have described, certainly lessens nuisance, but not to the full extent practicable. I often found, too, that the stokers in Durham habitually left the central charging hole open for some time after charging, thus producing much smoke.

Even in the best constructed ovens the effects of dilapidations, interfering with the normal operation of any provision against nuisance, have to be guarded against. These dilapidations occur in various ways, but the chief cause of them is the alternate expansion and contraction of the structure from the changes of temperature to which it is subjected. These are accidents requiring constant watchfulness. Even the large culvert arrangement is not wholly exempt from them, since on my visit to the ovens at Dodworth I found smoke issuing in considerable quantities where there ought to have been none, in consequence of the warping of the iron covers of the charging openings of the ovens. In Durham the covers used are made of thick slabs of fire-clay which does not warp, and the covers are luted down.

Prevention of nuisance from coking in piles.

The nuisance from pile coking is less easily dealt with, but Mr. E. T. W. Jones, the public analyst for Staffordshire, has been good enough to inform me of a method invented by his father, Mr. Edward Jones, by which it may be greatly reduced. The invention was patented (1859, No. 2158). Mr. Jones availed himself of the chimney or dome *a*, Fig. 11, by which to draw off the products of combustion by means of a fan or exhauster, or by means of a chimney draught, through flues mostly underground proceeding from it; and he condensed the condensible products by arrangements similar to those ordinarily employed for such a purpose at gasworks. Plate XI., is a plan of a mode of arranging the piles and flues which Mr. Jones found to be convenient, and it is noticeable that it permits of indefinite extension in any direction; *a a* are the heaps or piles, from the central domes of each of which a cast-iron pipe of 1 foot diameter proceeds, communicating finally with a similar main-pipe *b*, of 2 feet diameter. This pipe terminates in the fan or exhauster *c*, which draws upon all the pipes and drives the collected products into the upright or "continuous" condenser *d*. In order to prevent over-heating of the pipes, they are laid within a square brick flue *e*, which is made to communicate with the air in certain places, namely, just outside each pile at *f*; and again, by leaving the top of the flue open near the junction of each branch flue

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with the main flue at *g*. In order to promote condensation in the main flue, this main is surrounded by water, instead of air, which is made to flow through the brick flue or channel in which it is laid. All the pipes of course are duly sloped, so that products condensed in them shall pass into the main, and from it into a reception tank *h*. Soon after lighting the heap, the top of the dome or chimney is closed by an iron plate or damper, and the draught may be controlled in a similar manner. Mr. Jones states in his specification: "I usually cover the coke heap " either wholly or partially with coke or mine dust or other powdered " solid, or, instead of powdered coke or other solid, I sometimes use a " covering either of metal or other material, for the purpose of regu- " lating the draught or for protecting the coke heap from the excessive " action of the air." Mr. E. T. W. Jones informs me that he saw the arrangement when his father had it in use, and that it was thoroughly effective in preventing nuisance. The condensed hydro-carbons were intermediate in character between coal tar and shale oil, and were commercially valuable. He says that the coke was harder than that usually produced by burning in heaps.

Prevention of nuisance from coking at cement work;

The nuisance from coking at cement works may be done away with, as already mentioned (p. 74), by carrying the smoke from the ovens by a long flue to a tall chimney shaft. The adoption of some of the processes of cement making, already described (p. 72), by doing away with the ordinary slurry floor, also does away with the coking nuisance.

from breeze making.

The only attempt I have seen made to lessen the smoke nuisance from "breeze making" about Dudley was at the works of J. Jones and Son, at Windmill End, where a flue is provided, passing down from the summit of the dome of each of two ovens to an underground flue, which discharges itself into a moderately-tall chimney, which also receives the smoke from a set of 22 coke ovens. In this way part of the nuisance has been abated; but still, at each charging in of coal, abundance of smoke issued from the open doorways. Perhaps the flue is not large enough.

I am not aware of any plan by which nuisance from quenching the coke can be avoided. At some works it is customary so to arrange that the ovens to be drawn on any one day are drawn very early in the morning before the population is up and abroad. When flued ovens which work boilers are in use, the oven is damped off from the flue before quenching, since the steam, if it entered the flue, would cool it too much, and interfere with the draught. Several managers whom I have spoken to on the subject of a supplementary light flue to carry off steam to the chimney shaft, say that such an arrangement would in their opinion be ineffectual to take off the large amount of vapour which bursts forth on the first application of the hose.

Ignition of Spoil Banks.

The Ignition of Spoil Banks.

It is a common thing in colliery districts to see heaps of shale or "bass," in the neighbourhood of the coal pits, on fire. It is commonly said that they fire spontaneously; but while not denying the possibility of this when the shale has much pyritic matter mixed up with it, or where oily tow or rags from the mines or engine-rooms, &c. have been cast away among the shale, yet I am certain that often the firing is not spontaneous, but either due to the tipping of hot cinders or furnace ashes on the heap, which may be regarded, perhaps, as an accidental cause, or else to intentional firing, either mischievously or with the view to reduce the bulk of the material. I have already referred to the fact that the shale, interstratified with coal, contains an

admixture of coaly matter. This is sufficient in amount to maintain a smouldering combustion when once fire has been kindled; but, in addition, a very superficial examination of a spoil bank shows that it contains, mixed up with the shale, more or less actual coal; indeed it is a common thing to see poor people searching the heaps for these pieces. When a heap becomes fired, unless the fire be quickly put out, the combustion spreads deeply into the heap and extends often to a long distance; and if the heap be a very large one, or be constantly added to, the ignition may continue for years. Only a few months ago I saw a railway embankment, which had been constructed with "bass," either wholly or in part, on fire for a considerable distance, the fire having spread to it from an ignited spoil bank near some iron works close by. The result of the combustion is a red flaky ash which is sometimes sold for making garden paths.

The smoke and fumes proceeding from a burning spoil bank are copious, very disagreeable, sulphurous, and suffocating; and, when the heap is near houses, the nuisance is sometimes such as to render the houses quite uninhabitable if the wind brings the smoke in that direction. Under such circumstances people have had to get up in the night and leave their houses. The fumes are irritating to the organs of respiration, and in this and other ways injure health. The fumes cause a sense of obstruction of breathing, coughing, and expectoration, headache and sickness, and affect unfavourably the general health, especially of children, and are particularly irritating to persons suffering from pulmonary diseases. In a row of 14 cottages, standing about 40 yards from a heap on fire at Darfield Main Colliery, and which I saw burning, Dr. Sadler, the Medical Officer of Health, found, on inquiry instituted on account of complaints made to him, cases of bronchial irritation in every house in the row. Mr. Hartill, the Medical Officer of Health for Short Heath, Staffordshire, mentions, in his annual report for 1878, an instance of this form of nuisance, and says that the fumes affected the purity of the air for more than two miles around the heap. The nuisance occurred at New Invention, and was a matter, he tells me, of common complaint. He says he has frequently experienced in his own person the irritating operation of the fumes upon the respiratory organs.

I am informed by Mr. Grocutt that the best way of dealing with a heap on fire is to isolate the portion on fire by means of a trench dug down a few feet into the ground on which it stands, to fill this cutting with sand, and then to saturate the ignited part with water. But the fire ought never to be permitted to extend so far as to require so costly a proceeding; it should be carefully extinguished with water as soon as it is observed.

MANUFACTURE OF COAL GAS.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
— 1875 -	Gaslight and Coke Company.	Bow Common.	—
Nov. 30, ,, -	Leamington Gas-works.	Leamington.	—
Dec. 16, ,, -	Plymouth and Stonehouse Gas-works.	Plymouth -	Manufacture of sulphate of ammonia.

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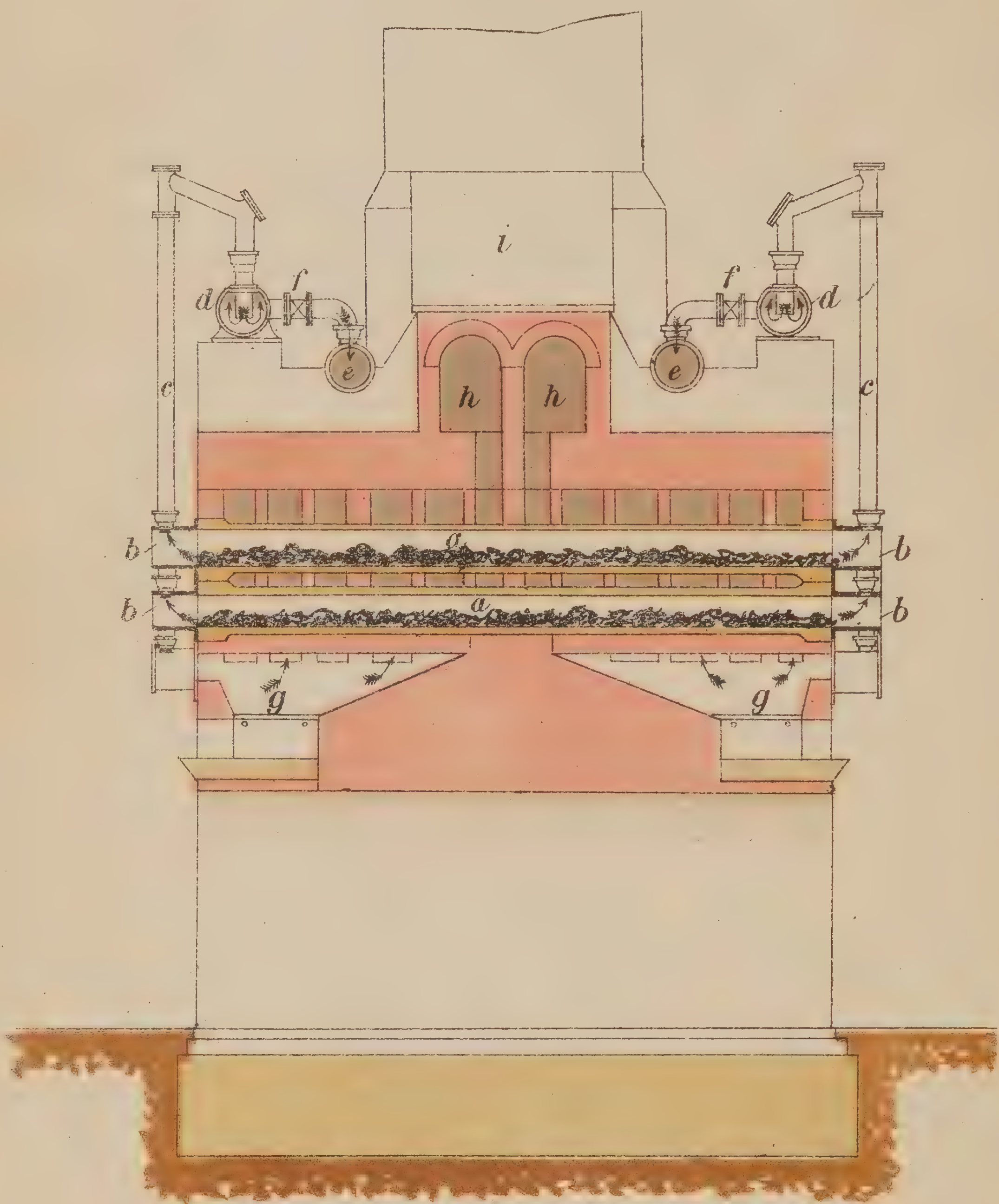
Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 2, 1876 -	Warrington Gasworks.	Warrington.	—
April 6, „ -	Loughborough Gasworks.	Loughborough.	—
„ 26, „ -	Nottingham Corporation Gasworks.	Nottingham.	—
„ „ „ -	Ditto - -	Basford.	—
„ „ „ -	Ditto - -	Radford.	—
May 16, „ -	Corporation Gasworks.	Manchester.	—
„ 30, „ -	Corporation Gasworks.	Salford.	—
June 1, „ -	Gasworks -	Leeds.	—
Nov. 16, „ -	Gaslight and Coke Company.	Haggerstone.	—
„ 28, „ -	Corporation Gasworks.	Hereford.	—
„ 30, „ -	Lancaster Gasworks.	Lancaster -	Manufacture of sulphate of ammonia and distillation of tar.
Jan. 11, 1877 -	Portsea Island Gasworks.	Portsmouth.	—
Sept. 12, „ -	Dublin Gasworks	Dublin.	—
April 9, 1878 -	Huddersfield Gasworks.	Huddersfield.	—
June 1, „ -	Edinburgh Gasworks.	Edinburgh.	—
Dec. 2, „ -	Phœnix Gasworks	Vauxhall.	—
„ 4, „ -	Commercial Gasworks.	Stepney.	—
„ „ „ -	Ditto - -	Bromley.	—
„ 16, „ -	Southampton Gasworks.	Southampton.	—
Jan. 11, 1879 -	Swansea Gasworks.	Swansea.	—
Feb. 13, „ -	Gaslight and Coke Company.	Bromley.	—
Mar. 26, „ -	Gas Company's Works.	Worcester -	Manufacture of sulphate of ammonia.
April 26, „ -	Gaslight and Coke Company.	Fulham.	—
May 8, „ -	Birmingham Corporation Works.	Saltley.	—
June 5, „ -	Gaslight and Coke Company.	Beckton, North Woolwich.	Distillation of tar, manufacture of sulphate of ammonia, lime burning.
July 2, „ -	Elswick Gasworks	Newcastle-on-Tyne	Manufacture of sulphate of ammonia.
„ 9, „ -	Corporation Gasworks.	Dalmarnock, Glasgow.	—

Process of gas-making.

When coal such as is mostly used for the manufacture of gas is subjected in a close retort to destructive distillation, volatile matter is given off, and a solid carbonaceous matter, coke, remains behind. The volatile matter is in part readily condensable, and in part not readily condensable. The former condenses into a watery and a tarry matter, while the latter constitutes crude coal-gas. In the various processes of distillation of the coal, purification of the crude gas, and disposal of the condensed matters and refuse, offensive emanations are apt to be given

SECTION OF A BENCH OF RETORTS.
AT PHŒNIX WORKS, VAUXHALL.

Scale ⅛ inch to 1 foot.



a. a. Retorts.
b. b. Mouthpieces.
c. c. Ascension pipes which convey the Gas from Retorts.
d. d. Hydraulic Mains.
e. e. Relieving mains conveying the Gas away to condenser
f. f. Regulating valves.
g. g. Furnaces.
h. h. Flues.
i. . Chimney Shaft.

Dangerfield Lith 22. Bedford St. Covent Garden.

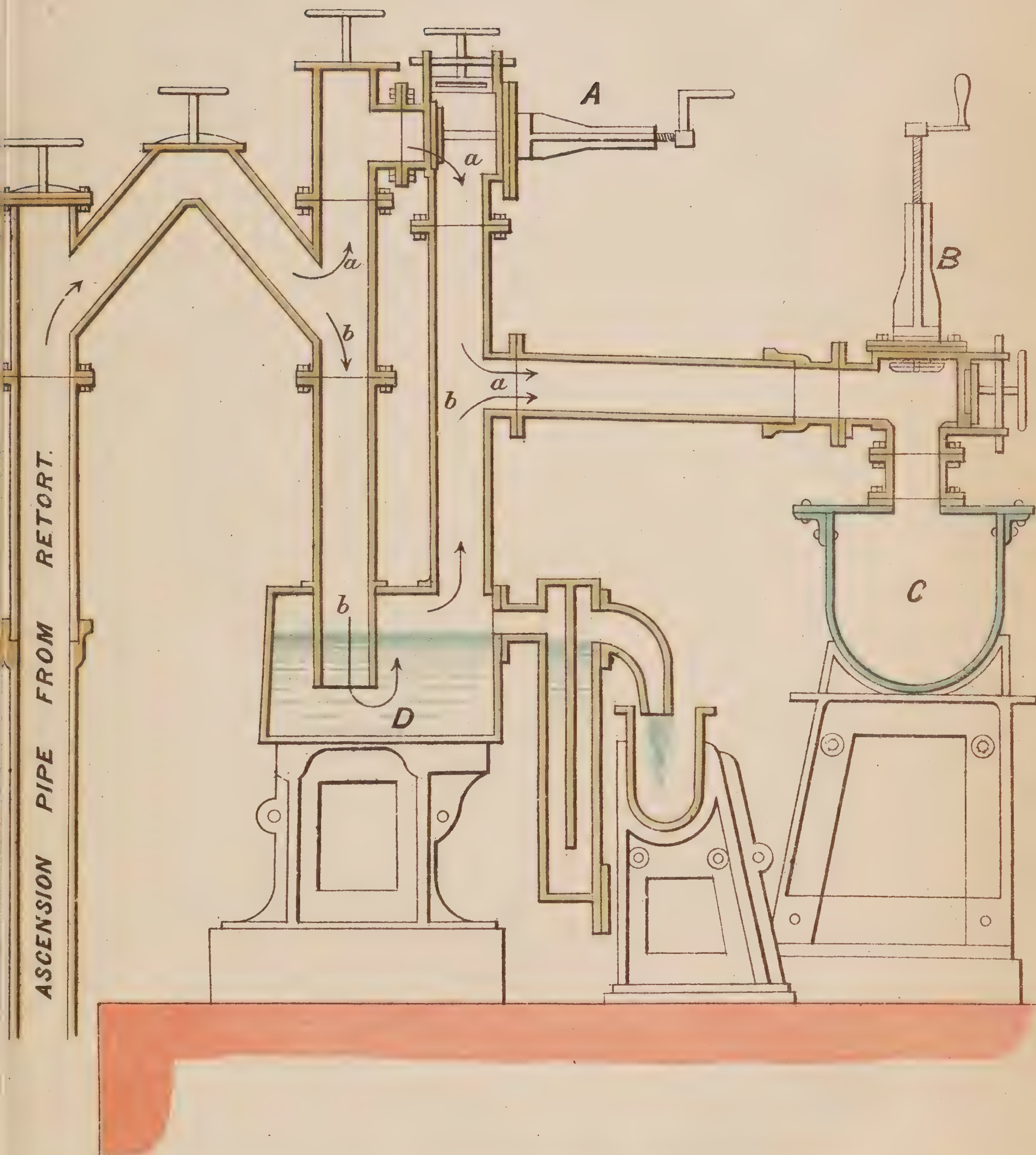
off, such as cause the neighbourhood of gasworks to be shunned by all who can afford to reside elsewhere.

The retort-house of a gasworks is usually an oblong building, consisting merely of the four walls and a pretty lofty roof, ventilated mostly by a capacious doorway at each end, by openings in the side walls near the eaves, and by louvre openings or other openings in the roof. In the middle of the retort-house mostly are situated the benches of retorts. In each bench the retorts are arranged in sets commonly of three to seven together, each set having its own furnace, and the whole bench being provided with appropriate furnace flues and the first appliances for carrying off and dealing with the volatile products. Such a bench of retorts as arranged at the Phœnix Works, Vauxhall, is represented in section, in Plate XII. It will assist me in explaining such details as it is necessary to give here. The retorts now preferred are made of fire-clay, being in fact, long fire-clay tubes either round or  –shaped, and either constructed so as to be open at both ends, as in Plate XII., *a*, when they are called "through" retorts (since they run without interruption right through the bench), or else so as to have one end closed and one end open; these are called "single" retorts. "Single" retorts are not much used in large works. The internal diameter of a retort is about 14 inches. The length of a through retort varies a little in different works. An ordinary length is about 18 or 20 feet. The single retorts are usually about half this length. The retort ends do not project beyond the face of the bench in which it is set; but to the end is attached an iron mouthpiece *b*, of the nature of a prolongation of the retort, which mouthpiece does extend outside the bench, and is thus removed from the direct action of the fire. From the top or from the side (according to position in the set) of each mouthpiece proceeds a pipe *c*, the "ascension pipe," which conveys away the volatile matters through a dip pipe into the hydraulic main *d*. Looking at the Plate it will be seen that each set of retorts is heated by two furnaces *g g*, one on each side of the bench. Beneath each furnace is an ashpit, which is usually filled with water. From this mode of arranging the furnaces it comes to pass that the retort is not quite equally heated along its whole length, and that there are two parts, namely the middle parts of the two halves of a through retort, which are most heated, and three parts, namely the middle of the entire retort and the two ends near the mouthpieces (and especially the latter) which are the least heated. This is important to keep in mind. The fact is obvious to anyone who looks through such a retort when the covers have been removed and the retort is empty. Two kinds of covers or lids are in common use to close in the ends of the mouthpieces. The ordinary lid is a plate of iron made to fit the mouthpiece, upon which, when adapted, it is pressed down tightly by means of a cross-bar and screw, after which screwing down, the edges are luted round with an appropriate lute. The other is what is known as Morton's patent lid. In this arrangement the edge of the mouthpiece and the part of the lid which comes in contact with it are both faced with surfaces so true as to be gas-tight when one is applied to the other: and, whereas the ordinary lid is entirely removed when the mouthpiece is opened, the Morton lid is attached to the mouthpiece with a hinge, like a door, and there is an ingenious arrangement of levers for keeping it firmly in its place when the lid is closed down. The *hydraulic main* is a large horizontal pipe carefully set as absolutely level as possible, extending above the whole length of the bench on each side. It is always about half full of condensed matters, chiefly tarry matters, into which the pipe which conveys gas

from the retort (called the "dip-pipe") actually dips in such a way as that the gas entering the hydraulic main has to bubble up through the tarry matter. This arrangement serves also to seal the dip-pipe when the corresponding retort is open, and so to prevent atmospheric air being drawn into the main. In some works the hydraulic main is dispensed with, and in place of it an arrangement more or less similar to that figured in Plate XIII., which represents the arrangement at the Fulham Gasworks, is adopted. The object sought is to permit the gas during the distillation, when the retort is closed, to pass at once to the condenser, so as to reduce pressure upon the retort; but when the retort is opened for drawing the charge or for recharging, to seal the pipe in the same way that the hydraulic main seals it. A and B are two valves, and when both are open the gas passes upwards in the direction of the arrow *a* through the valve A, and so into the pipe C, which conveys away the gas to the condenser. But when the retort is open or about to be opened, the valve A is closed down, as shown in the Plate, and then any gas is made to pass in the direction of the arrow *b*, through a box D, containing water, into which the pipe dips as it would dip into a hydraulic main. From the hydraulic main, above the tarry matter it contains, a pipe conveys away the crude gas to be dealt with for cooling and purification.

Before entering on this latter subject it will be convenient here to describe the mode of charging and discharging the retorts, and what takes place in the actual distillation. To begin with the discharging. A small number of lids of retorts on the same row are loosened by a workman, when a small explosion, with corresponding little gush of flame, occurs, and then the retorts are discharged in succession. In the case of through retorts the operations are conducted as nearly as possible simultaneously at the two ends. The cover is removed and a workman proceeds with an appropriate tool to rake out the incandescent coke which the retort then contains. It is either raked out on to the paved floor of the retort-house or into an iron barrow, or in some works (arranged for the purpose with an elevated platform corresponding with the retorts) into a vault below. At some works a part of the coke, as it is raked out, is directed by means of an iron shoot into the furnace below. The coke is quenched with water, usually thrown upon it from buckets, but sometimes with a hose. This operation of quenching ought to be performed upon the first portions of coke drawn, and immediately they are drawn. Prior to re-charging the retort, a strong iron tool, or rod of iron slightly curved and fashioned at the end like a screw, technically termed an "augur" or "roger," is thrust up the ascension pipe in order to ensure its clearance of tarry and carbonaceous matters which are very apt to accumulate there and to choke it up. This accumulation may occur in any part of the pipe and may not be within reach from the lower opening; in that case the upper end of the pipe has to be opened and the pipe cleared from that end. When all the retorts whose lids had been loosened have thus been discharged, the workmen set about re-charging them with the coal, which has been placed conveniently within reach in a heap upon the pavement. Where "through" retorts are in use the charging is performed as nearly as possible simultaneously at the two ends. The workmen on the one side call out to those on the other side to begin. Two modes of charging are commonly in use, viz., by the shovel or by the scoop. The use of the shovel is almost, but not entirely, confined to small works. A workman throws in the coals shovelful after shovelful, until he has introduced thus the requisite quantity, which he does his best to distribute equally along the bottom of the retort. The form of the scoop is indicated by its name; in length it is such as to reach to the end of a

SECTIONAL PLAN OF VALVE – ARRANGEMENT AT FULHAM GAS – WORKS.



Arrangement of Valves shews retort to be open for charging. During work Valve A would be open as well as Valve B.

Dancerfield. Lith 22, Bedford St. Covent Garden.

single retort or half-way along a through retort. Its width varies according to the size of the retort and the amount of charge and the number of scoopsful which the manager prefers to put in. It always widens out a little from the handle towards the end. Prior to charging, a scoop is filled with coal, and it is then lifted by three men. One stands at the cross-handle and two near the opposite end, where their business is to raise the scoop by means of a bent bar of iron passed under it, and direct it into the mouth of the retort. The man at the cross-handle pushes it in as far as it will go, inverts it, and withdraws it as quickly as possible, leaving the charge at the bottom of the retort. The three men then set to work to refill the scoop, when the same process is repeated, and, if necessary, this is done a third time. In some cases a shovelful or two of coal is then thrown in by hand. As soon as the charging is completed another workman, having a lid ready prepared with luting, pushes back into the retort with an instrument called a "backer-up," any coal that may have been spilt into the mouthpiece. This proceeding is called "backing up." As soon as that is done he claps on the lid and fastens it down. Smart and tolerably experienced workmen can charge with three scoopsful, back up, and close the lid in 35 seconds. I have more than once timed them. Less experienced men, such as are met with in some country works, take longer. But shovel-charging is the slowest process of all. It takes a full half minute longer than putting in the same charge with the scoop. At some works that I have visited, as for example at Manchester, a hydraulic machine is in use for drawing and re-charging the retorts, and it is said to work more expeditiously than hand labour. Machine-charging was once tried, I was informed, at the Dublin works, but broke down; and the manager told me that in his opinion no time was really saved by it. At any rate, it has not come into anything like general use. Both in the process of discharging the retorts and of charging them, more or less smoke escapes into the retort-house, and finds an exit from it by the various openings in the walls and roof. Much steam of a more or less offensive kind is given off when the coke is quenched. The process of discharging and re-charging goes on at orderly intervals throughout the day and night.

At Worcester, a large arched fire-brick chamber or muffle, having a floor of tiles, is used, together with two single retorts beneath it, all heated by one fire. The chamber is 14 feet from front to back, 5 feet wide, and 2 feet high in the middle. The charging is effected by a shovel. It took a man $1\frac{1}{2}$ minutes to charge one of the retorts; the charging of the chamber must have taken very much longer.

Purification of crude gas.

Crude coal-gas issues from the hydraulic main at a high temperature, the actual temperature varying with that at which the coal has been distilled; and in this state it contains readily condensable matters, such as tarry matters and watery vapour, which separate from it as soon as its temperature is sufficiently reduced. In order to reduce its temperature and enable it thus to deposit these more readily removable matters, it is passed through the "*condenser*." This is an arrangement of iron pipes freely exposed to the cooling influence of the external air. The form of the arrangement varies in different works; that which is preferred, as it appears to me, where this operation is most carefully attended to, is what goes under the name of the "annular" condenser. It consists of a series of large vertical pipes, each of which has a smaller pipe within it, and the gas is made to pass in the interval between the two pipes. The gas is thus not only exposed to the cooling influence of the air on the outside of the larger pipe, but also to that of the air within the smaller pipe. At the Manchester Gasworks, where very

The condenser.

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great pains are taken to ensure good condensation, the condensation is brought about by means of large pipes laid horizontally in a tank of cold water. It appears undesirable that the temperature should be reduced below 60° or 59°, so as to avoid the impoverishment of the gas by deposition of valuable hydro-carbons. Of course the condenser should be in total length and width of tube so arranged that time shall be afforded for the proper deposition of condensable matters. These fall down into a space below, from which they run off to the tar-well. The matters deposited are, roughly, tar and ammoniacal liquor, respecting both of which more has to be said. All the tar, or nearly all, and a proportion—it is said about one fourth—of the ammoniacal compounds (as much as the watery vapour present will take up when condensed) ought to be here deposited. From the condenser the gas passes to the *exhauster*, or air-pump: it need not be described here; the object of it is to reduce the pressure on the retorts behind, and so lessen leakage and prevent decomposition of the gas generated, while it is in the retort, by hastening its removal, and to drive the gas forward through the purifying apparatus.

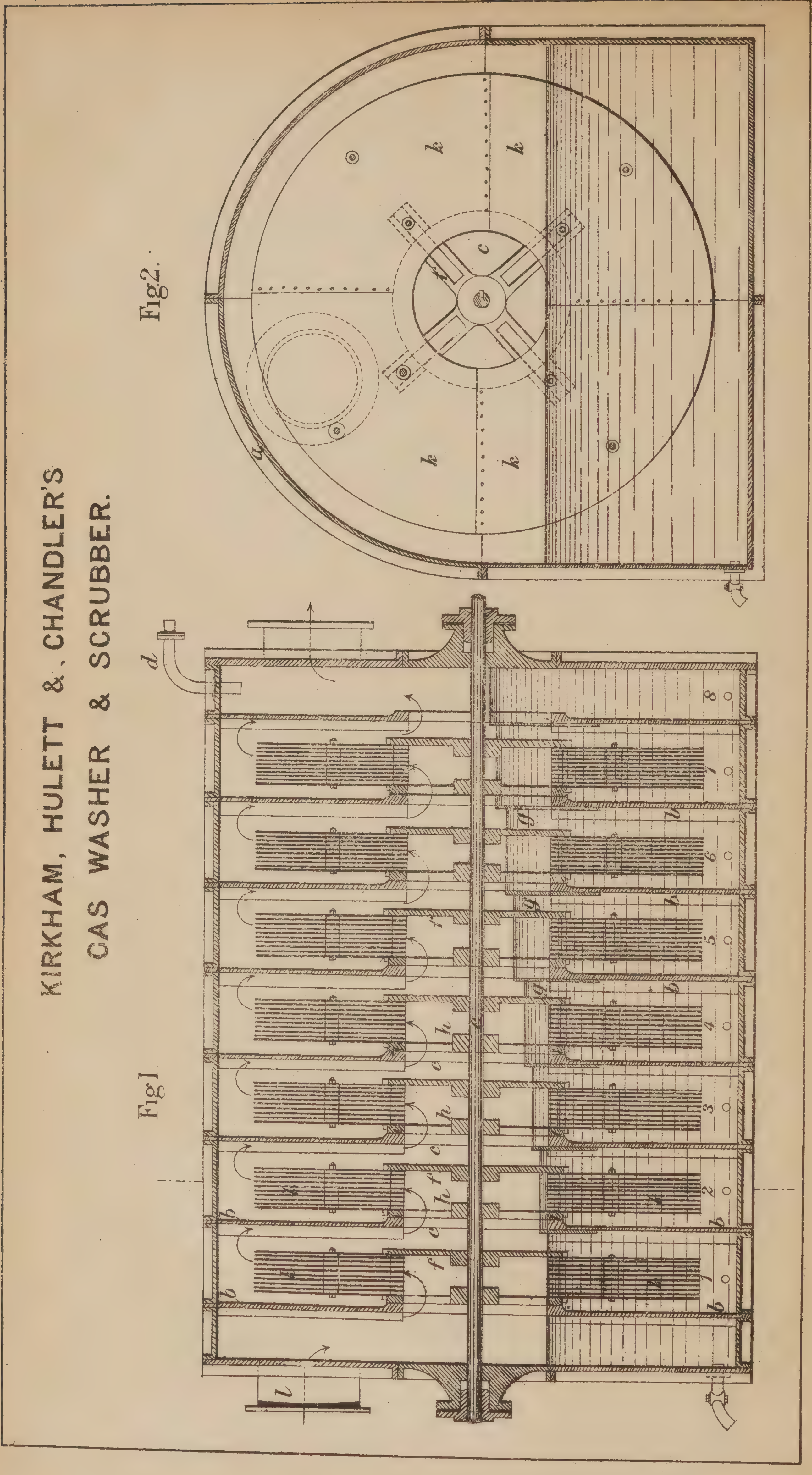
The exhauster.

As the gas leaves the exhauster it is too impure to be used for illuminating purposes. It is unnecessary for me to enter minutely into the chemical nature of the impurities it contains; it may suffice here to say that it contains carbonic acid, sulphuretted hydrogen, ammonia, bisulphide of carbon, and some cyanogen compounds, variously combined, together with such tarry matter and aqueous vapour as may have escaped condensation in the condenser, and under some circumstances perhaps a little sulphurous acid. The object of the purification is to remove these as completely as is economically practicable. The carbonic acid, sulphuretted hydrogen, and ammonia ought virtually to be all removed, and as much as possible of the bisulphide of carbon, although in most country places no attempt or no systematic attempt is made in the last direction. And it is important that all this should be done cheaply and by the use either of chemical substances of little primary cost or of substances which, after having been employed in this way, can be subsequently utilised in other chemical processes. Some valuable matters are removed in the process of purification, and it is, or ought to be, an aim to recover them. Such as these are sulphur, ammonia, and the cyanogen compounds. As respects the two first the object is very generally attained, but little practically has yet been done as respects the last. The purifying agents most commonly used are water, lime, and hydrated oxide of iron. We will, therefore, consider these first.

Washing and scrubbing.

1. *Washing* with water, or "*Scrubbing*."—At most works "scrubbing" only is used, the washing being dispensed with; at others, but these are few, only washing it used, scrubbing being dispensed with; and in a few works the gas is first washed and then scrubbed. The object sought in both cases is to cause the water to absorb virtually all the ammonia and with it as much of the sulphuretted hydrogen, carbonic acid, and cyanogen compounds as the existing ammonia can combine with, to form sulphide, and carbonate, and cyanide, or sulphocyanide of ammonium. The resultant solution in water is known technically as "gas-liquor." Now in order to attain this object satisfactorily four things are necessary, viz., a sufficiently low temperature which the condenser ought to have secured, a sufficiency of water, sufficient time for thorough absorption of the matters to be absorbed, and sufficient points of contact between the water and the gas.

The best kind of "*washer*" is, I learn, believed to be Anderson's. In it the gas is made to bubble up through a series of shallow trays



DANGERFIELD, LITH. 22, BEDFORD ST. COVENT GARDEN.

charged with water or weak gas-liquor. At the new works of the Commercial Gas Company at Bromley I saw another kind of washer, on the principle of the cascade washer already described as in use at some artificial manure works. It was said to answer very well, although it appeared to me to require, as now constructed, some improvements to ensure the equable distribution of the water along its several stages and an equable flow over all parts of their edges.

The two kinds of "*scrubbers*" most generally found in use are Mann's and Livesay's scrubbers. Mann's scrubber is a circular tower having a series of trays arranged at intervals within it, each tray supporting a layer of coke, while at the top there is a distributor, by means of which water or weak liquor is thrown down upon the coke so as to fall from stage to stage, trickling down through each layer of coke until it reaches the bottom, where it runs away to a tank. The distance between tray and tray is about 4 feet 6 inches, and the coke is said to be best loosely laid to a height of about 4 feet on each. In the Livesay scrubber the cavity is fitted with rows of thin deal boards, arranged at right angles to each other alternately. At the Swansea Gasworks, and at some other works I have visited, salt-glazed pipes and perforated tiles are arranged within the scrubber instead of coke, and the arrangement is said to work well. But whatever the arrangement preferred (and probably each has both its advantages and disadvantages), care should be taken that there be no stinting of height, so that plenty of time be given for the thorough action of the solvent action of the water, the gas being kept in contact with it long enough to part with all that water can possibly take up. It is only then that the scrubbing of the gas can be said to be thoroughly effected. Any tarry matter which has escaped the condenser ought to be arrested by the scrubber, and so washed down with the ammoniacal or gas liquor. At some works it is a practice to pump up liquor from the tank and to pass it through the scrubber as often as may be necessary to bring it up to a saleable strength.

A form of washer and scrubber, invented and patented by Messrs. Kirkham, Hulett, and Chandler, (1877, No. 4928), has been very successfully adopted at some of the works I have visited. Inasmuch as it appears applicable to the absorption of gases in other manufactures besides that of coal gas, it seems to be worthy of description. Plate XIV., Fig. 1, represents the apparatus in a longitudinal, and Fig. 2 in a transverse section. It consists of a cast iron vessel or box *a*, divided by partitions *b* into any desired number of chambers, which communicate with each other through openings *c* in the centre of the partitions, and the lower parts of which contain water (or other liquid suitable for the purification of the gas), which is admitted into the interior of the vessel *a* through the supply pipe *d*, and flows thence through the several openings into the several chambers. The level of the liquid in the chambers gradually decreases in height from chamber 8 to chamber 1, the height being regulated by means of plates *g*, secured to the partitions ***b*** so as to cover more or less the openings in these partitions. Through the centre of the apparatus passes a horizontal shaft *e*, upon which at a short distance from the partitions are keyed a number of discs *f*, corresponding with the number of chambers; a similar number of perforated plates or bosses *h* being also keyed upon the shaft *e* so as to bear, at their peripheries *i*, against their adjacent partitions. Between each of the discs *f* and bosses *h* are arranged in clusters any desired number of annular plates *k* of thin metal, which are connected together and to the discs and bosses by bolts, distance pieces or washers being interposed between the several annular plates in each cluster in order to maintain

them at a short distance apart, and to allow of the passage between them of the gas that is to be washed. The result is that each chamber contains a cluster of annular plates which, by means of suitable gearing to the shaft, are made to revolve in it, and in revolving the plates become constantly kept wet with the liquid at the bottom of the chamber. The gas to be scrubbed is admitted at *l*, and enters the nearest chamber of the series through the opening in the partition *b*, whence it passes between the annular plates in the first cluster, over their edges, and thence through the opening of the next partition into the next chamber, and so on through all the chambers to the last one in the direction shown by the arrows. It is obvious that as the liquor flows from chamber 8 to chamber 1 it gradually increases in strength. The chief advantages specially claimed for this washer are, the small space it occupies, that it works with a minimum of pressure, that it is not necessary to reduce the temperature so low as 60° to ensure effectiveness, and that it takes out every trace of ammonia from the gas once traversing the machine.

The "purification" proper of gas is, as has been said, usually effected with hydrate of lime (slacked lime) and hydrated oxide of iron, the latter being mixed with twice its bulk of sawdust. At some works the one only, and at others the other only is used, but for the most part both are used. An old practice, which was extensively used about 25 years ago, was to mix the lime with water into a cream, and to use this alone. It was called the "wet-lime" purification in contradistinction to the "dry-lime" purification, that is to say the use of the powdery hydrate. But the use of wet lime has been almost universally abandoned. Still, however, I have seen it in use at some works, so that it becomes necessary to describe the process.

Use of wet-lime.

In wet-lime purification the cream of lime is introduced into a circular tank, through which the gas is passed, and where the gas and cream of lime are agitated together by a stirrer working in it by means of a mechanical arrangement or gearing outside. As the lime becomes saturated with the impurities of the gas, it is run out into subsiding pits or tanks. This practice is still pursued at the old works of the Nottingham Corporation. There are here four purifiers, which are emptied and refilled in succession, the gas being passed first through the oldest or foulest lime, and last through the newest lime. The subsiding tanks here are made of wrought iron; there are two of them, and they are capable of holding 12 charges each. They are only covered with loose planks. When sufficient subsidence has taken place the supernatant liquor is put into the furnace ashpits instead of water, and the offensive matters which escape in its evaporation pass away through the fire to the stack. The "blue-billy," or deposited lime, is used, as was formerly the almost constant practice, for luting the covers of the retorts.

Use of dry lime and oxide of iron.

Dry lime and oxide are put for use into "purifiers" or square or oblong iron boxes provided with covers capable of being raised, and the edges of which dip, when the cover is down, into a groove running all round the box and containing water, which thus acts as a lute. The purifiers may be of any size required by the extent of work to be done. Some are extremely large. Those at the Commercial Gasworks at Bromley are 40 feet square. Each box is provided within with a series of perforated trays, but mostly with sieve-like partitions or screens of wood, which are removable in sections. There may be from two to seven tiers of such screens in a box; and according to the depth of the material laid on the screen, and the distance of the tiers apart will be the requisite height of the box. It rarely, if ever, exceeds 8 feet. The gas is admitted below, and passing through layer after layer of the purifying material escapes at last at the top, from which a pipe conveys it away altogether or into

another purifier. The gas is in almost all works sent through a series of such purifiers. When lime and oxide are both used, it is a common practice to put both the lime and the oxide into the same purifier, laying the lime upon the lowest tier and oxide upon the upper tiers. At other works separate purifiers are used for lime and for oxide. The selection of lime or oxide and the amount of use made of each when both are used, depend a good deal upon circumstances, and not least upon the readiness and cost at which each is obtainable. Oxide of iron is only capable of removing the sulphuretted hydrogen, while lime is capable of taking away not only that gas, but also carbonic acid, and, when used in a certain way, some of the bisulphide of carbon also. In the London works, where a standard of sulphur in compounds other than sulphuretted hydrogen (no sulphuretted hydrogen at all being permitted) is fixed by law, the use of lime has hitherto been regarded as indispensable.

Chemistry of dry-lime purification.

It is necessary now to point out what happens when scrubbed gas is passed through a hydrate of lime purifier. The lime combines with the carbonic acid to form carbonate of lime, and also with sulphuretted hydrogen to form sulphide of calcium and water. Up to a certain time both these substances exist in the purifier; but as the passage of gas goes on, the carbonic acid entering with the gas begins to decompose the sulphide formed, forming more carbonate of lime, and sending away the sulphur again as sulphuretted hydrogen. In the end, the lime purifier comes to contain little or no sulphide, but practically all the lime has become converted into carbonate. By testing the issuing gas it can be determined when all the lime has thus been converted, and then the lime has done its work and must be removed. The gas, cleared of carbonic acid, now passes to the oxide purifier. It still contains sulphuretted hydrogen and bisulphide of carbon. The oxide removes the sulphuretted hydrogen. The reaction is a simple one: the sulphur of the sulphuretted hydrogen replaces the oxygen of the oxide of iron, while the oxygen combines with the hydrogen to form water. And now the only thing to be dealt with is the bisulphide of carbon. The method in ordinary use of getting rid of this depends upon the following reaction. The agent employed is sulphide of calcium. With this substance bisulphide of carbon unites so as to form what was called by Berzelius a sulphocarbonate, in other words a carbonate of lime, in which oxygen is throughout replaced by sulphur, the formula of it being $Ca\,S, CS_2$. The sulphide of calcium purifier, for removing the bisulphide of carbon, is prepared by interpolating an ordinary hydrate of lime purifier between the lime purifier used to abstract carbonic acid (and which discharges from it sulphuretted hydrogen without admixture of carbonic acid,) and the oxide of iron purifier. This fresh lime is converted into sulphide, which is thus capable of absorbing bisulphide of carbon, and does absorb it. And so long as no carbonic acid enters, this goes on, both sulphuretted hydrogen and bisulphide of carbon being absorbed. But as soon as the first lime purifier ceases to act in consequence of having become saturated with carbonic acid, and carbonic acid consequently begins to enter the sulphide of calcium in the second lime purifier, it displaces both sulphuretted hydrogen and bisulphide of carbon, and the arrangement for removing the latter is disturbed. Hence, it is important to guard against such an accident. The best mode of guarding against it is, as soon as the sulphide of calcium is prepared in the purifier, and before carbonic acid can pass on from the lime purifier, to alter the order of passage of the gas, to send it from the first lime purifier at once into the oxide purifier, guarding the latter with a lowermost layer of lime,

and then into the prepared sulphide of calcium purifier. In this way carbonic acid and sulphuretted hydrogen are removed first, and then the bisulphide is removed last of all, and, as no carbonic acid reaches the sulphide of calcium purifier, the bisulphide is retained as sulphocarbonate of lime.

Use of sulphate of iron.

In some works other chemical substances are used in purification of gas. In place of oxide of iron, sulphate of iron is sometimes used. It has the advantage of separating ammonia as well as sulphuretted hydrogen, the ammonia decomposing the sulphate to form sulphate of ammonia and oxide of iron, which last decomposes the sulphuretted hydrogen and forms with its sulphur a corresponding sulphide. At the Manchester Works chloride of iron with sawdust is used with the same object, but not in full supersession of oxide.

Use of "ammonia-material."

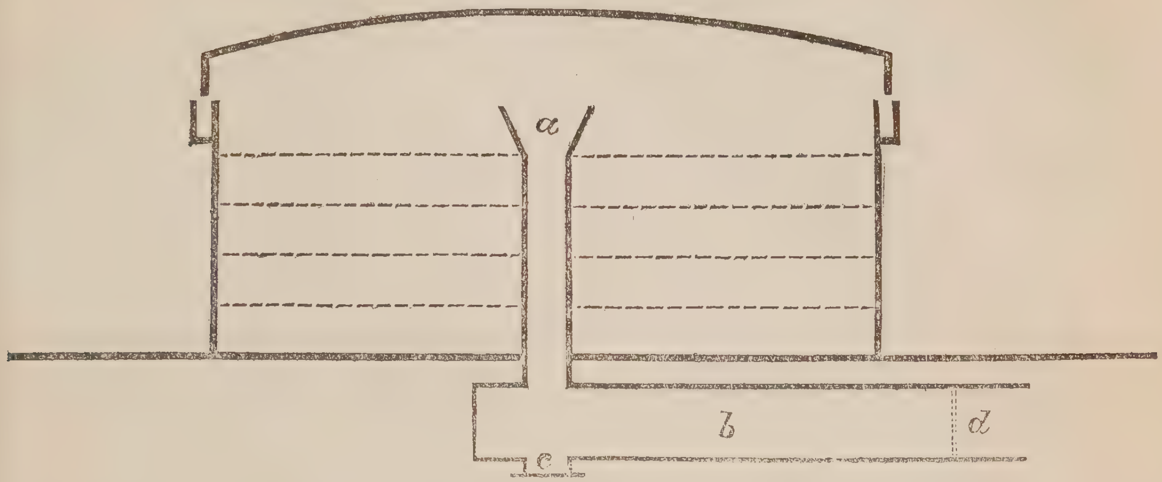
Sawdust unmixed with anything else is used at the Edinburgh Gasworks to absorb ammonia that has escaped the washer used there, and the manager says the men would not work at the purifier if it were not used. In other works special means are used to remove ammonia. One of these means is sawdust which has been saturated with strong sulphuric acid, and which then passes under the name of "ammonia-material," (p. 50). This and other modes of getting rid of ammonia ought to be quite unnecessary if the previous scrubbing arrangements are good, since the gas ought to leave the scrubber deprived of all but a mere trace of that constituent of the crude gas. But they are useful agents to have at hand in the event of any accident affecting the efficiency of the scrubber.

Process of emptying a purifier.

Purifiers are ordinarily situated in a special house or building ventilated from the sides. When a purifier has become saturated with the matters it is intended to separate, it is emptied of its contents and re-charged with fresh material. The gas is turned off from the purifier and diverted into a fresh purifier of the same description, and the cover of the old one is elevated. Workmen now enter and shovel out the fouled material from tier after tier, until the bottom is reached, removing the sieves or partition in sections as each tier is cleared of material. In many gas-works, especially the smaller and country gasworks, the purifiers stand upon the ground floor, and in that case the material is thrown out upon the surface outside, and wheeled away in barrows. But in many large, and especially in some more recently constructed works, another arrangement is made. The purifiers are placed upon an elevated floor or platform which leaves a space or chamber below, along the roof of which the entrance and exit pipes of the purifier pass, and on to the floor of which the foul material can be discharged. In this case one or more channels or conduits are made to pass vertically through the purifier from below, terminating above in a funnel-shaped mouth between the top tier of material and the cover. Below, this channel enters the exit main in the roof of the lower chamber, so that the gas, after passing through the purifying material, escapes by these channels to the exit main. But these channels are also used for the discharge of the foul material, and the arrangement for effecting this is as follows: In the lower part of the main pipe opposite the point at which the channel enters it, is an aperture of sufficient size, which, when the purifier is in use, is closed by a gas-tight and luted cover. When the purifier is to be emptied, the main pipe is closed so as to cut off its communication with the general system of such similar mains, and then the door or cover in the lower part opposite the channel of the purifier is opened. The workmen shovel out the foul material through the channel, and it falls through the main on to the floor

of the chamber below. The following rough diagram may serve to illustrate the arrangement.

Fig. 14.



Channel for exit of gas and discharge of purifier. *b.* Gas main. *c.* Opening in main for passage of material through it. *d.* Arrangement for breaking off gas communication.

Revivification of oxide of iron.

The "spent" lime is usually heaped up somewhere in the yard to await removal by farmers or others who will take it. The foul oxide, however, is useful again, but to render it so, it has to undergo the process of "revivification." This process depends upon the fact that when the sulphide of iron formed is freely exposed to the air, the oxygen of the air acts upon it, combines with the iron to reform oxide of iron, while the sulphur separates in a free state. Hence, after revivification, the material consists not merely of oxide of iron and sawdust, but of oxide of iron, sawdust, and sulphur; the sulphur does not interfere with the potency of the reformed oxide as a purifying agent, except in so far as its presence serves to reduce the relative quantity of oxide in a given bulk of the material. This process of fouling and revivification may be repeated with the same material many times, the sulphur continually increasing in quantity until it becomes desirable to use the material no longer. It may then contain 40 per cent. or more of sulphur. The material thus fouled is sold as "spent oxide" to sulphuric acid makers (p. 171.) The process of "revivification" is performed at the gasworks by spreading the oxide upon a floor or platform, either within a house or protected from the weather by a roof, and turning it over from time to time. Some evolution of heat takes place, and when due care has not been taken ignition has even resulted.

Nuisance from gasworks.

It is scarcely necessary to say—the fact being notorious—that gas works rarely fail to occasion nuisance, more or less serious, wherever they may be established in a populated neighbourhood. They spoil it for residential purposes. The nuisance is constant day and night, varying only with the direction of the wind and the state of the weather. Nor is it the immediate neighbourhood of the works alone that may suffer; the offensive effluvia, in which the odour of sulphur compounds and offensive hydrocarbons predominates, sometimes extend to a long distance, such as a mile or more. Gasworks indeed are usually situated either in the outskirts of a town among a poor population not very sensitive in the matter of stinks, or, for mechanical reasons connected with the distribution of the gas, at the lowest level available, where such a population usually gravitates. It is probably for this reason that complaints are rarely made; but when from any cause the nuisance is extended over a large area, and becomes trouble-

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

some to persons occupying a better class of residences, then an outcry arises, and in such cases, from time to time legal proceedings have been taken to bring about the abatement of the nuisance. In a few instances, however, within my knowledge, town gasworks are conducted so as to create no nuisance giving occasion for serious complaint among a population certainly far from poor or insensitive.

Injury to health.

In 1857, when the Medical Officers of Health, newly constituted at that time by the Metropolis Local Management Act, united into an association for mutual assistance in their work, the nuisances from gasworks were so great that one of the first things done was the appointment of a committee, of which I was a member, to inquire into the question. We visited every one of the London gas-works and gathered all the information we could from our colleagues and others as to the influence of the effluvia upon the public health. One distinguished chemist, Dr. R. D. Thomson, since deceased, was an active member of the committee. The printed report of that committee is now before me as I write. Since that time, however, gas making has undergone vast improvements, and much that the report contains is inapplicable to existing conditions. It says nothing about damage inflicted by the effluvia upon public health, for the reason, as I very well recollect (since I drafted the report), that nothing definite was ascertainable upon the subject. It was found impracticable to eliminate the influence exerted by other more certainly injurious conditions, to which the poor populations most exposed to the effluvia from the works were subjected. And the same difficulty still exists. Beyond such disturbances as loss of appetite, headache, sickness, &c., nothing definitely pointing to a poisonous operation of the effluvia has been determinable, and such effects as these may be simply due to the disagreeable impression made upon the senses.

Sources of nuisance.

The sources of nuisance from gasworks may be one or more of the following:—The issue of smoke and offensive vapour from the retort-house, the process of emptying the purifiers, and the deposition of spent lime in the yard, the effluvia from accumulations of "blue-billy," the use of luting made of blue-billy for the retort lids, the revivification of oxide, the free exposure of tar or ammoniacal liquor to the atmosphere, and, lastly, the removal of the various refuse matters, such as spent lime, tar, or ammoniacal liquor from the premises. Each of these sources of nuisance require separate consideration.

1. Smoke, &c. from retort-house.

1. Smoke and offensive vapours arising from the retort-house. I am not here alluding to the issue from the chimney stalk of the furnace, since this smoke is usually delivered at a considerable elevation, and can only exceptionally create nuisance, especially when coke and not coal is used as fuel. The nuisance is from the smoke, &c. that escape at a lower level from the openings at the sides and in the roof of the retort-house, and which commonly becloud the entire neighbourhood of the works. The smoke is that given off into the retort-house during the discharging and recharging of the retorts, offensive gases, &c., issuing from leakages at their mouths, and offensive steam proceeding from the quenching of the coke with water. *a*. Smoke, &c. issuing during the discharging of the retorts. A charge thoroughly coked gives off, under the most favourable conditions, no smoke worth speaking of while it is being drawn; but as it sometimes happens that the charge has not become thoroughly coked when drawn, some parts at least are apt to be less perfectly distilled than others, and this is especially likely to be the case with that part of the charge which lies nearest to the mouthpiece. Portions of the charge thus incompletely coked give off smoke on being drawn. Secondly, choking of the ascension pipe may occasion a pressure

within the retort which, when the lid is removed, may give rise to an issue of smoky flame. Mr. Wright, of the Bromley Works, is of opinion that there is less choking of the ascension pipe when the use of the hydraulic main is dispensed with. Thirdly, during the distillation, tarry and carbonaceous matters, partly dust from the charge, always accumulate within the mouthpiece, the comparatively low temperature of which favours the condensation of the former in this situation. When a retort is opened for drawing, such matter is found not only lining the inside surface of the lid (which is of no consequence) but lying in little irregular heaps at the bottom or on the sides of the mouthpiece, and even hanging down from the roof of it. This accumulation, always present, is often added to by the workman clearing the ascension pipe before the charge is drawn. When the incandescent coke, as it is being drawn, passes over this tarry matter, it ignites it, and causes the evolution of large quantities of very offensive smoke. Few things produce more smoke in burning than tarry matters. It is the first quantity of coke drawn that thus produces the smoke. The remainder of the charge should give off none, and usually does give off none, since the inner surface of the mouthpiece has been usually scraped clean by the first act of raking. The largest accumulation about the mouthpiece which I saw in the course of my inquiry was at the works at Worcester, where the coal appeared to be distilled at an unusually low temperature. *b.* The issue of smoke during the charging of the retorts is the result of the first operation of the heated surface of the retort upon the part of the charge in contact with it. The coal in contact with the retort is being distilled at a low temperature, at which volatile substances rich in carbon are generated, and begin to burn with evolution of much sooty matter. The longer the time occupied in charging the retort, the more certainly and in greater abundance will be this issue of smoke. Hence it is found to be greatest in works where shovel charging is wholly or partially practised, and least in works where the charging is effected more rapidly with the scoop. The first issue of smoke usually appears about 12 seconds after the first scoopful has been introduced. *c.* The quenching of the coke gives rise to a burst of watery vapour, thus either superseding the smoke that issues commonly from the first raking in the drawing of the charge or mingling with it. This vapour is more or less charged with sulphuretted hydrogen, due to the decomposition by the water of the sulphide of iron left in the coke after distillation. Coal contains usually more or less sulphur (p. 96), in the form of a persulphide of iron, only half of which sulphur passes off in the process of distillation. A highly sulphurous coal is one which gas makers avoid, inasmuch as its use involves more subsequent purification of the gas; but more or less sulphur is scarcely avoidable, and the offensiveness of the vapour in question will depend primarily on the quantity originally present in the coal. In some gasworks I have visited, the vapour has little perceptible odour of sulphuretted hydrogen. *d.* One other source of nuisance in the retort-house may be mentioned. It is a trifling thing comparatively, but great nuisances are sometimes made up of many trifling ones. It is leakage of tarry matters and gases from the retort mouths. Imperfect closing is the cause, and it is said by some gas managers to be more likely to happen when the Morton's patent lid is used than when the old luted lid is employed, in consequence of the corrosion of the faced surfaces, and the injury they receive from the rough usage they get from the workmen in removing accretions, &c. Some gas managers who have used both kinds of lid tell me that they are going back to the old luted lids in preference, on this account. On the other hand, Mr. Trewby, the manager of the Beckton works,

tells me that they have over 4,000 Morton's lids in use there and have no trouble from leakage. He says that when leakage occurs it is due to want of attention, and that he is fully satisfied with these lids and as to their many advantages. The gases will of course leak most when the ascension pipe is clogged.

2. Emptying purifiers.

2. The emptying of the purifiers, notably of the lime purifiers, and the disposal of the spent lime by deposition in the yard (for the emptying of the oxide purifiers, if they have no lime tier in them, is not usually a nuisance) is the principal source of nuisance from the gasworks, and especially of the nuisance which is complained of at a distance from the works. It is easy to understand how this comes about. Volatile sulphur compounds are the most offensive of all chemical inorganic effluvia, and a very little of them in the atmosphere goes a long way where stink is concerned; and moreover the public have a special wholesome and not unnatural dread of sulphur-stinks. When a lime purifier, the contents of which have been thoroughly converted into carbonate of lime, is discharged, no very observable nuisance arises; what little stink there may be is limited to the works themselves, and the lime thrown out quickly becomes inodorous. But it is otherwise when the lime contains sulphur compounds, such as sulphide or sulpho-carbonate of calcium and other matters which have escaped the previous purifying processes of condensation and scrubbing: for the spent lime gives off, when disturbed and exposed to atmospheric action, and especially to the decomposing operation of the carbonic acid of the atmosphere, all the offensive sulphur compounds which it may have absorbed, especially its sulphuretted hydrogen and its bisulphide of carbon; and this escape goes on more or less during a long time, or until the surface of the heap of spent lime becomes indurated sufficiently on the surface to exclude the air from the interior.

3 "Blue-billy."

3. "Blue-billy" is now rarely a source of nuisance, the wet-lime process having been generally abandoned, but formerly it was one of the principal sources of gasworks nuisance. It used to be stored in pits dug in the earth or in tanks open to the atmosphere; and not only did the offensive emanations when it was undisturbed, and tenfold more when it was disturbed, spread widely around the works, but the soil in the neighbourhood became offensively saturated with soakage from the pits. The use of the lime sludge as luting served as an additional source of nuisance from the retort-house, by the offensive emanations thrown off as the luting became hot.

4. Revivification of oxide.

4. There ought to be no nuisance arising from the revivification of the oxide of iron, and in the best conducted works there is none, or if ever there is nuisance, it arises from some accident, or temporary imperfect working of the scrubbing arrangements. But in former times I have known the nuisance such as to give rise to serious complaints. The offensiveness, when it occurs, arises from the evolution of ammonia, and there is a smell as if some cyanogen compound were present, which is probably the case. This nuisance can never arise where the previous scrubbing of the gas has been thoroughly efficient.

5. The exposure to the atmosphere of tar and ammoniacal liquor from the condenser has now and then, in small works, been a source of nuisance. I have seen these matters run out from the condenser by an open gutter along the ground, an arrangement which can only be designated as grossly slovenly. But commonly the nuisance of exposure arises during the removal of the tar and liquor by carts or barges, into which they are pumped from the tar-well or liquor tank. The removal of the spent lime from dry purifiers in carts through a populated neighbourhood, and its deposition in an improper place, have also some-

times been a serious source of complaint. It has been so at Plymouth, the trade nuisances near which town were brought a few years ago specially under the notice of the Board. In this instance the contractor for the spent lime used to convey it from the works in open carts a distance of about 250 yards to a wharf known as Queen Anne's Battery, and used to allow it to accumulate there until the accumulation of a barge load rendered it worth his while to take it away. It occupied about a fortnight in summer, and about a week in winter to collect this quantity. The offensive odour was distinguishable from the other stinks of the vicinity, and the late Medical Officer of Health, Dr. Littleton, told me it was a nuisance at the barracks in the citadel, a third of a mile away.

Modes of prevention of nuisances.

1. From the retort house.

The remedies for the nuisances arising from gasworks may almost be deduced from what has preceded.

1. In respect of the nuisance proceeding from the retort-house. *a.* The smoke produced during the drawing of the coke may be reduced to a minimum: 1st. By taking care that when the retort is charged, the charge is duly distributed so as to ensure that the conversion into coke shall be as equable as possible throughout the charge. Some effort should be made that the layer of coal placed in the bottom of the retort be rather thinner in those parts where the heat is least than in those parts where it is greatest. 2nd. By very careful and effectual "backing up." This operation is too often done in a most perfunctory manner, and sometimes is neglected altogether. The coal should be pushed back well into the retort. 3rd. By careful attention to the condition of the ascension pipe at its upper as well as at its lower end. The clearance of it should follow, not precede, the drawing of the charge, and none of the matters that fall from it should be left in the mouthpieces. 4th. By careful scraping and cleansing of the mouthpiece from tarry deposits and accretions, both at the bottom and at the sides, and in fact all round, before the charge of coke is drawn. The matter scraped out should be carefully collected in a shovel, and be either taken away altogether or thrown upon the coals intended for a future charge. At some works I have seen it simply scraped out upon the floor on to which the incandescent coke subsequently falls; in this case the nuisance is as great as when the mouthpiece is not scraped at all. 5th. By the quenching of the first coke raked out immediately on its being raked out. This again is a proceeding commonly performed in a loose and slovenly manner. I have said that the water is usually brought in a bucket and thrown upon the coke. Instead of the workman being ready with the water to throw on the coke first drawn, it is not by any means unusual for the charge to be half or more than half drawn before the workman with the first bucketful makes his appearance, and all this time the charge is smoking. Hence the preference to be given to the supply of water by a hose, which a workman can always be ready with at the side of the workman who is drawing the charge, or in the vault when the coke is drawn into a vault. But Mr. Trewby tells me he has this objection to the use of the hose, namely, that the stoker who is drawing the charge is then placed in a scalding atmosphere, whereas, when water is thrown on by buckets, care can be taken not to do this when the man has his rake far in and consequently when part of his body is over the coke. This objection evidently does not apply where the coke is drawn into a vault. *b.* The smoke produced in charging is lessened by increasing the rapidity of the process. Scoop charging is in this respect preferable to shovel charging. Time is the thing to be saved, and it would be saved to the extent of several seconds if more than one

instrument were used in charging a retort requiring two or three scoopsful. As many scoops as are requisite might be filled and stand ready to be run in rapidly one after another before the charging is commenced: the time occupied in filling the same scoop once or twice would then be saved. No time is saved by using larger scoops so as to be able to charge with two scoopsful instead of three. The slowness with which the heavier scoops are manipulated delays the completion of the process. I timed the charging under these circumstances at Saltley: it occupied 35 seconds. I have mentioned that sometimes, after the scoops, a shovelful of coal is thrown in. The reason of this is the thinning by wear of the part of the retort most exposed to the heat, which necessitates the placing of coal in greater quantity at that particular part than in other parts. It makes a difference of a few seconds in the time occupied before the lid is applied, and may make the difference between smoke and little or no smoke. The remedy is a new retort. *c.* The nuisance from sulphurous vapour given off on quenching the coke is one for which the use of lime mixed with the quenching water has been suggested. I do not know of its ever having been tried. It would probably so far alter the appearance of the coke as to damage its sale. The occurrence of the nuisance to a serious extent would probably lead a manager to consider the propriety of changing his source of supply of coal, since, if there is much sulphur left in the coke, there is sure to be too much to be removed from the gas. *d.* The remedy for leaking lids is too obvious to require mention.

But it is not easy so to control the rough class of labourers who work in a retort-house as to get such matters as the above attended to as they should be, and hence it is desirable that the retort-house itself should be so constructed and arranged that smoke emitted from it may be as little a nuisance as possible. It is desirable with this end to give no opportunity for the escape of smoke anywhere but at the summit of the roof, and that the benches of retorts should be so situated as that the smoke from them shall readily escape at free openings provided there. The objection managers have urged, when I have suggested this to them, is that the closure of ventilating openings in the side walls and ends of the retort-house would render the place too hot to work in; and no doubt it would be so in a small and narrow house, unless artificial means were taken to increase the draught through the roof or through a ventilating shaft rising from it. But at the new works of the Commercial Gas Company at Bromley, where the ventilation is entirely effected by a wide opening along the whole ridge of the roof of the retort-house, beneath which stand the benches of retorts, there is no such excessive heat, because not only is the ventilation very free through this opening, but because the retort-house is exceedingly wide and capacious. The Committee of Health Officers before mentioned suggested that "perhaps a remedy might be found in the closure of the ordinary " openings at the roof, and in place of these, forming at the upper part " of the retort-house one or more communications with the chimney " or tall shaft which carries off the heated air and smoke from the " furnace."

2. From spent lime.

2. The spent lime nuisance. A great deal of this nuisance in country works would be avoided if more care were taken with the previous processes of condensation and scrubbing, which are often conducted at such works in a most imperfect manner. Where the removal of bisulphide of carbon is not required either by law or popular demand, this nuisance ought not to exist. By thoroughly good scrubbing, a good deal of the carbonic acid may be removed, and a lime tray at the bottom of each oxide

purifier may be all that is necessary to use of this substance. But in using lime at all it is, from the nuisance point of view, better to use it in a separate purifier, because then by due testing of the issuing gas it is possible to discover when all the sulphur first absorbed has been driven off by absorption of carbonic acid. When this occurs the purifier should be thrown out of the series, and it may then be emptied without nuisance. But where lime is the only purifier used, no special absorbent of sulphur such as oxide of iron being used, this is of course impracticable; and lime purifiers fouled with sulphur compounds must be emptied. It is the same with a foul lime purifier, used specially for the absorption of bisulphide of carbon after the gas has passed the oxide purifiers. The problem to be solved is, how to empty these so as not to create nuisance, and, as respects bisulphide of carbon, how to dispense with foul lime as its absorbent altogether. First as to emptying. The plan of emptying down a conduit into a lower floor, which has been mentioned, would at first sight appear better than emptying over the edge of the purifier on to the floor of the purifying house, since it affords facilities for discharging the refuse lime in such a manner as to avoid a good deal of nuisance. Thus it is not absolutely necessary to discharge it upon the floor, and then carry it away in barrows. A cart or trolly running upon a tramway might be run beneath the discharge opening, the cart might even be provided with a cover, and a channel or funnel of sacking or other material might be used to conduct the foul material from the discharge opening through the cover into the cart. Such a sacking channel is used at Widnes and other places, in discharging bleaching powder from the chambers in which it is made. It appears a simple precaution which would probably assist in reducing the nuisance. Such offensive matter, too, ought not to be exposed in the open air, poisoning the atmosphere of the neighbourhood until it may be convenient to remove it from the premises. It ought to be conveyed away at once in covered carts or covered barges (with due precautions in loading them), to be disposed of innoccuously.

Talking to Mr. McMinn, the manager of the Fulham Gas Works, upon the subject of emptying lime purifiers, he objected to the arrangement last described on the ground that the disturbance of the material in this mode of emptying was much greater than in the method adopted at his works, since each shovelful had to be carried or thrown through a space of air a certain distance to reach the mouth of the funnel, and that during all this time offensive gases were being given off. At the Fulham works, where, by Mr. McMinn's courtesy, I was given an opportunity of watching closely the mode of emptying. The process is as follows:—After drawing air through the purifier, the cover being just a little raised for about an hour, merely with a view to remove loose gas from it, the cover was fully raised. The purifier was in three tiers each having a superficial area of 40 feet by 20 feet or thereabouts. The first thing done was to water the whole surface of the top tier for about ten minutes by means of a distributor flattened out at the end like a spade, which from time to time the workmen dug into the material in many places. The whole surface was then covered with large sheets of sacking, four sheets, each covering a quarter, being used for the purpose. The only part left uncovered was a space about three feet wide across the middle, where the removal was to commence. The watering is done at the suggestion of the gas referees, on the supposition that the diffusion of dust is one source of nuisance. Two men on each side now begin the removal at the uncovered part, and work towards opposite ends of the purifier; and as they proceed and find it necessary, they roll back more and more of the sacking until they get to the end, and then

each begins in the middle again and works to the opposite end of his side of the purifier. It occupied the four men 24 minutes to remove the lime from one tier. Large shovels are used and the material is taken up in them with as little disturbance as possible: no dust arises, the water having made the material sufficiently coherent to allow of its being raised by the shovel in clean masses. Each of the above-named workmen is attended by two labourers or carriers, who receive and carry away the material in small sacks with which they are furnished, one having his sack filled while the other is carrying his sack away, emptying it and bringing it back again. The sack is slit half down one side, and, when it is filled sufficiently, the flaps thus formed fall over and cover up the contents. The labourer carries away on his back and shoots the spent lime down into the waggon that is to convey it away. The waggon is of iron, the bottom of it being formed of two portions which by a lever arrangement can be made to fall from the middle so as to constitute a shoot. It is provided with a cover of sacking made to the shape of the waggon, with side pieces which can be tied over the sides. The cover is in two portions, so that the top part can be rolled back to the sides during loading. A series of such waggons stand ready to move in succession, a tramway on the ground being provided for the purpose at the side of the row of purifiers. The cover being turned back, a waggon is run into the interior of a wooden shed of the form depicted in Photograph 1, which shed travels also upon a tramway, the rails of which are outside those for the waggons. The opposite sides of the lower part of the shed, those at which the waggon is run in and run out, are provided with folding doors, and when both pairs of doors are closed the waggon stands within a close shed. At the side of the upper part next to the purifier, and opposite to it, the woodwork is deficient, but in place of it there is a heavy curtain of sacking, kept tense by an iron rod below, which curtain hangs down within the shed and closes it in these situations. As each sack is brought to the side of the purifier, its contents are shot down under the edge of the curtain, and, by means of an inclined board in this situation, are directed into the waggon beneath. When the waggon is full the doors at the exit side are opened and the waggon is run out and immediately covered over the top with the cover. In this condition it is run along a tramway about 100 yards to the barge lying in the river alongside, no material being spilt in the transit. The arrangement at the river side is this:—The barge is moored close to the edge, and the filling of it is commenced at one end, and in an orderly and regular way continued to the other end. A wooden stage, which is attached by hinges to the bank or edge of the wharf, is let down above the barge, so that the part of the barge which has to be filled lies immediately beneath it, and all round this stage a very wide sheet or curtain of sacking is affixed by means of iron pins on which it is hung. This curtain hangs down on all four sides of the stage, so that no dust nor vapour can escape from the interval between the stage and the barge beneath it. The tramway on which the waggons run is continued along the stage, and, at the spot where the lime is to be discharged from the bottom of the waggon, there is an oblong opening corresponding in length with the bottom of the waggon, and provided with a cover to be used when a waggon is not being discharged. The loaded waggon is run over this opening, the cover of the waggon not being removed. Suspended above is a cover of sacking set in a framework, and this is then let down like an extinguisher over the waggon so as to cover it up completely. In the side of this extinguisher-like cover there is a circular hole at the spot which corresponds with the lever at the side of the waggon, and through this

GAS WORKS,

1. LOADING WAGGONS WITH SPENT LIME FROM THE PURIFIER.

GAS WORKS,

2. WAGGON UPON THE PLATFORM OVER THE BARGE. SQUARE COVER DESCENDING.

GAS WORKS.

3. DISCHARGING SPENT LIME FROM THE WAGGON INTO THE BARGE.

the workman works the lever, and causes the bottom of the waggon to fall, when its contents are to be discharged into the barge. Immediately this is done the square cover is elevated, and, the cover of the waggon being turned back a little, workmen with shovels clear away and push down any material that has adhered to the bottom. This does not occupy longer than ten seconds, and then, the waggon covering being replaced, the waggon is run back to be refilled in due succession. But before this is done, and as soon as the square cover is raised, some shovelsful of "flyers" (a carbonaceous dust collected from the top of the banks of retorts), are scattered upon the material newly discharged into the barge. As one part of the barge is filled, the barge is moved a little further on, and so on until it is filled along its whole length. As each filled portion comes into the open air earth is thrown upon the material so as to cover it up completely. When the barge is filled it moves down the river to the place where it is to be discharged at Beckton. Thus the whole process is performed under cover, and, so far as I observed, inoffensively. The processes of loading the waggons and barge are illustrated by the accompanying photographs taken by direction and under the superintendence of Mr. McMinn for the purposes of my report.

Attempts have been made to deodorise the material by drawing air through it before discharging it from the purifier, and so far as the material itself is concerned this proceeding has been successful. But the objections to the process, which have led to its abandonment wherever it has been tried, have been the difficulty of preventing nuisance from the offensive gases eliminated and the danger of explosions, which have happened occasionally. The practice has been to absorb the sulphuretted hydrogen thus drawn off by means of oxide of iron, but this substance will not arrest other offensive sulphur compounds, such as bisulphide of carbon, and the escape of this into the atmosphere has given rise to complaints as loud as those occasioned by emptying the purifiers without previous treatment. An attempt to dispose of those offensive gases by combustion has been followed by explosion of the apparatus. If spent lime be deposited upon land where it is likely to become a nuisance, it should be covered with earth patted firmly down upon it. There is not, so far as I am aware, any successful process, universally applicable, by which the material has been safely made inodorous without the creation of some fresh nuisance;* and hence arises the importance of the attention of chemists being directed to the discovery of some other method than the use of foul lime for the removal of bisulphide of carbon from gas.

And this brings me to notice two processes of purification which have been adopted experimentally with this object; one by Mr. Leigh, the Medical Officer for Health for Manchester, who has for many

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* Mr. John Barrow, of Clayton, Manchester, has, however, taken out a patent (1878, No. 891), for a method of dealing with the spent lime, which, although not yet put into operation anywhere, is sufficiently promising to appear worthy of notice. He proposes to mix the spent lime with gas liquor, either by washing the lime with it as it lies within the purifier, or by discharging the lime into liquor, or in some other way. In this way he expects to convert the sulphide of calcium into a carbonate, while the liquor will entirely become a solution of sulphide of ammonium holding the bisulphide of carbon in solution as a sulpho-carbonate. From this he proposes to make sulphate of ammonia. In that case the gases proceeding from the saturator will consist of sulphuretted hydrogen and bisulphide of carbon. After drying them in the way mentioned at p. 133 of this Report, he proposes to separate the bisulphide by passing the dried gas through an oil tower such as I have described in use at some oil-works (p. 164), after which the sulphuretted hydrogen can be dealt with in any of the ways mentioned under the head of "Sulphate of ammonia manufacture" (p. 133).

years made the chemistry of gas-manufacture a study, and the other by Mr. W. Marriott, of Huddersfield, whose method is at present being made the subject of experiment at the works of the Gaslight and Coke Company at Bromley, now working under injunction. Mr. Leigh's method consisted in the use of gas liquor, which by a process of distillation or otherwise he converted into sulphide of ammonium, which, on addition of excess of sulphur, readily absorbs bisulphide of carbon with deposition of the excess of sulphur. But the process was not sufficiently perfect to be continued at the Manchester Gasworks, where it was attempted to adopt it. Nor is it yet certain that when perfected it will be free from nuisance. In Mr. W. Marriott's process, a sulphide of sodium specially prepared for the purpose is used, and the process is being now tried at Bromley, because it is believed that it can be carried out without creating nuisance.

3. From "blue-billy."

3. The "blue-billy" nuisance. Of course great care should be taken, where wet lime is used, that the tank in which it is stored for deposition shall be absolutely watertight and effectually covered. The best mode of dealing with it, however, is that which, in 1857, I saw adopted at the Phœnix Works at Vauxhall. The waste lime was pumped into a close chamber or oven, and the hot air from the furnaces was made to pass first through flues beneath the floor of the oven and then through the oven itself and over the material contained in it, and thence to the chimney. In this way the waste was reduced to a plastery condition, in which it could be used inoffensively as luting, while the offensive volatile matters were carried off and discharged from the chimney stack at such a height as not to be a source of nuisance. Plate XV. represents a section of the ovens in use at that time. They were removed in 1874. The cause of their being given up was an unforeseen accident, which it is as well to record as a caution. The chamber was of course constructed of fire-brick, and the bottom was lined with sheet iron. Leakage occurred, however, into the ground, and the matters that leaked out spread in the ground extensively, and beneath the foundations of an adjoining building and of the chimney stack. Undergoing chemical change, the effused matter crystallised in the earth and caused such an amount of expansion as to split the building adjoining the ovens, and to throw the chimney stack out of the perpendicular.

4. From revivification of oxide.

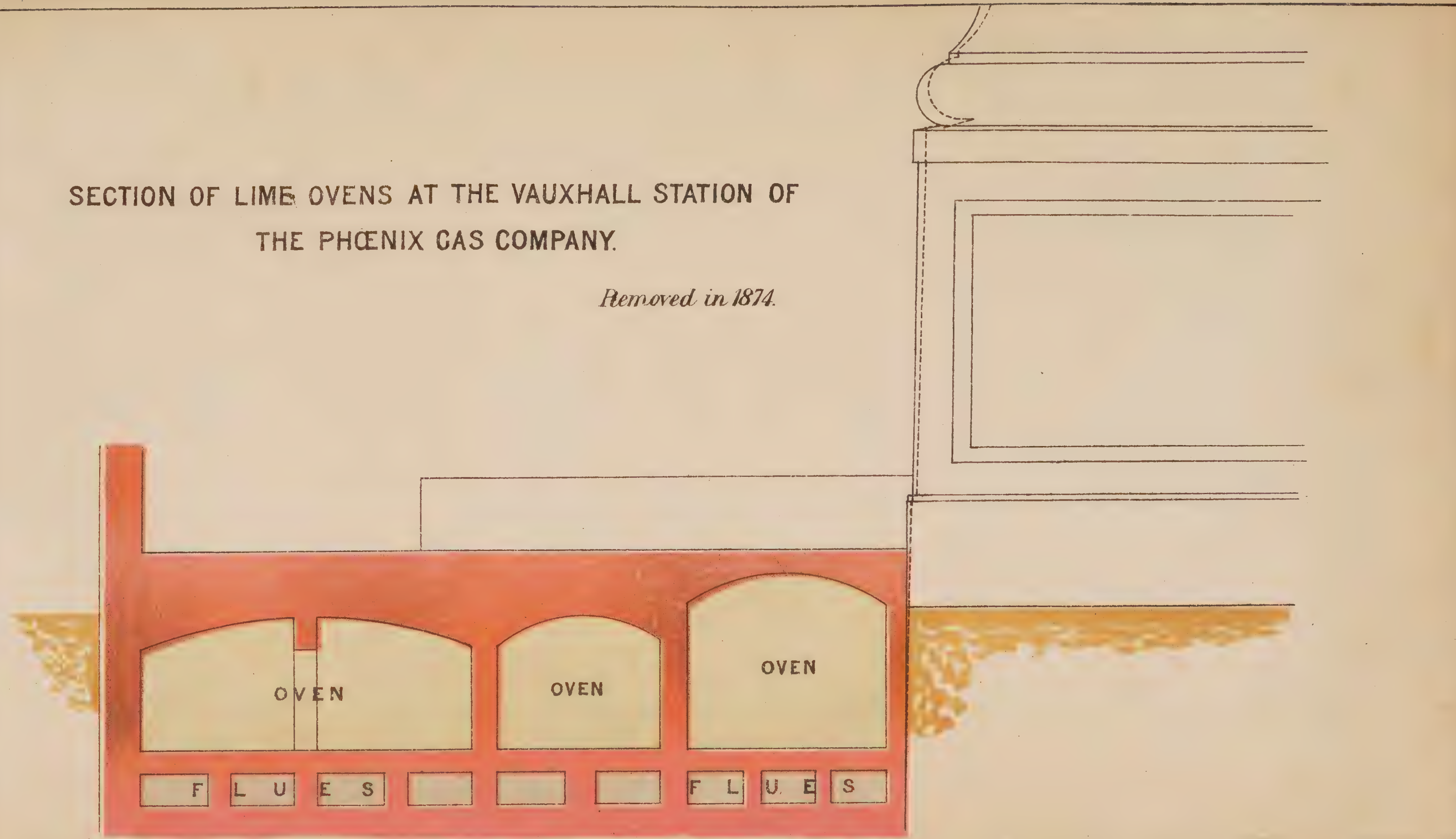
4. When, in consequence of defective scrubbing, ammonia compounds reach the oxide purifiers, a nuisance arises from the evolution of ammonia as the oxide heats in the process of revivification. Offensiveness in the process, therefore, should at once direct attention to the scrubber. But inasmuch as at times the scrubbing arrangements may be accidentally defective, even in the best managed works, it is preferable that the floor used for spreading the oxide should be, not the ground floor, but a floor at some part of the building above the tops of the neighbouring houses. In some of the best arranged works I have visited this precaution has been taken: the oxide floor has been placed above the purifier chamber, and the foul oxide, shot down from the purifiers into the vault below, has been raised by a pulley or lift to the floor above as quickly as possible after having been thrown out.

5. From tar and gas liquor.

5. I have already said all that is necessary as to the removal of spent lime. As respects tar and ammoniacal liquor, when the works at which they are to be utilised are sufficiently near, these refuse matters should be conducted to them in pipes so that there may be no exposure to the air. This is done at Manchester and other places. If they are to be conveyed in boats by canal, similar pipes should be laid from the works to the place of loading, and precautions should be taken there to

SECTION OF LIME OVENS AT THE VAUXHALL STATION OF THE PHŒNIX GAS COMPANY.

Removed in 1874.



DANCERFIELD. LITH. 22. BEDFORD S^T COVENT GARDEN.

obviate nuisance in the act of loading and during conveyance along the canal. The tank or hold of the boat should be covered, not with loose planks in the perfunctory way too commonly noticeable, but closely; and the tar or liquor should be introduced through a close conduit, provision being made for the escape of air from the tank through a box containing trays of hydrated peroxide of iron. When the conveyance is to be by rail, the best method is that in use at the Edinburgh Gas-works, the gas and liquor from which are sent as far as Falkirk; the tar and liquor here are pumped up into an elevated tank, from which they are run down by gravitation, as required, into close iron vessels shaped like boilers and placed each upon a frame like that of a railway truck, which is run into the works by a siding from the railway. These vessels are charged by a hose through a man-hole at the top without exposure to the air, and the charging hole is then closed by a cover tightly screwed down upon a proper washer. On arriving at an unpopulated spot on the side of the railway, about 300 yards from the Field Lane Works, the contents of the vessels are run out similarly, without exposure, into tanks from which pipes convey them to the tar works.

THE MANUFACTURE OF SULPHATE OF AMMONIA AND SAL AMMONIAC.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 10, 1875 -	Blott - -	Bow Common -	Tar distilling.
,, ,, ,, -	Percival Smith -	Ditto - -	Muriatic acid making.
Dec. 16, ,, -	Plymouth Gas-works.	Plymouth -	Gas making.
,, ,, ,, -	Harvey - -	Ditto - -	—
an. 6, 1876 -	Hill - -	Greenwich Marshes.	Sulphuric acid and manure making.
,, 11, ,, -	Burt, Boulton and Haywood.	Eling, Southampton.	Tar distilling and creasoting wood.
,, 25, ,, -	Stone and Tinson	Crews Hole, Bristol.	(Sal ammoniac.)
Feb. 23, ,, -	Crow -	Barking Level -	(Chloride of ammonium.) Tar distilling.
May 4, ,, -	Major - -	Awsworth, Erewash Valley.	—
,, 16, ,, -	Metcalf - -	Manchester -	Tar distilling.
,, 13, ,, -	Packard - -	Bramford, Suffolk	Sulphuric acid and manure making.
,, 20, ,, -	P. Spence -	Manchester -	Alum making.
,, 30, ,, -	Maguire - -	Ditto - -	Tar distilling and cart-grease making.
June 14, ,, -	Barrow - -	Clayton, Manchester.	Tar distilling.
Aug. 19, ,, -	Butler & Co. -	Upper Parting, Gloucester.	Ditto.
Oct. 16, ,, -	Wallace - -	Battersea -	Manufacture of sulphuric acid.
Nov. 30, ,, -	Lancaster Gas-works.	Lancaster -	Gas making. Tar distilling.
Jan. 10, 1877 -	Stampshaw Chemical Works.	Portsmouth -	Tar distilling. Manufacture of lamp-black.
May 14, ,, -	Charles Kurtz and Son.	Pump Fields, Liverpool.	(Sal ammoniac.)

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 14, 1877 -	Thacker & Co. -	Liverpool -	Tar distilling, oil refining, fat melting, &c.
Sept. 12, „ -	Kurtz & Co. -	Dublin.	—
Oct. 19, „ -	Hardman -	Milton, Burslem	Tar distilling. Manufacture of sulphuric acid.
Feb. 20, 1878 -	Alum and Smelting Company.	Goole - -	Manufacture of alum and sulphuric acid.
„ „ „ -	Hunter - -	Ditto - -	Manufacture of sulphuric acid and artificial manure.
April 2, „ -	Bouck & Co. -	Manchester -	Tar distilling. Manufacture of sulphuric acid, nitric acid, &c.
„ 3, „ -	Steuart - -	Clayton, Manchester.	—
„ 9, „ -	Close - -	Huddersfield -	Tar distilling.
May 23, „ -	Illingworth -	Bradford.	—
June 11, „ -	Sandiland Chemical Works.	Aberdeen -	Tar distilling. Manufacture of sulphuric acid, asphalte, and artificial manure.
„ 14, „ -	Lime Wharf Chemical Works.	Falkirk -	Tar distilling. Distillation of shale.
„ 18, „ -	Alum and Ammonia Company.	Glasgow -	Tar distilling.
„ 28, „ -	Kelly & Co. -	Swansea.	—
July 17, „ -	Hall - -	Redbridge Southampton.	Tar distilling. Manufacture of sulphuric acid, artificial manure and alum cake.
Jan. 24, 1879 -	Chance Brothers -	Oldbury -	(Sal ammoniac.) Alkali and sulphuric acid making, &c.
Feb. 13, „ -	Forbes - -	Old Ford -	Manufacture of sulphuric acid.
Mar. 25 „ -	Gas Company -	Worcester -	Gas-making.
April 1 „ -	Nicholson & Sons	Hunslet, Leeds -	Manufacture of sulphuric acid, &c.
„ 3 „ -	Illingworth -	Leeds.	
May 8 „ -	Spence & Steuart	Nechells, Birmingham.	Manufacture of sulphuric acid.
June 5 „ -	Gaslight & Coke Company.	Beckton -	Gas-making, tar distilling.
July 2, „ -	Elswick Gasworks	Newcastle-on-Tyne.	Gas-making.

Material used—gas-liquor.

The ordinary material from which sulphate of ammonia is made is the ammoniacal liquor produced at gasworks. I have in a former Report described its preparation from the liquor resulting from the distillation of bones, and at a later part of this Report, p. 166, I shall have to mention the use of liquor arising from the distillation of shale; but in this place I propose to consider only its preparation from gas-liquor. The liquor may arrive in barges or in tank carts, or in railway tanks specially arranged for the purpose, or it may be conducted to the works by pipes direct from the gasworks. The liquor contains the ammonia in the form of carbonate and sulphide of ammonium, and the strength of the liquor is usually stated by the number of ounces of strong sulphuric acid (sp. gr. 1,850) which are requisite to saturate a gallon of it (*e.g.* 10 oz. strength, 20 oz. strength, and so on). The strength of the liquor varies considerably, according to the works from which it has been received.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

Process.

The old process which I saw in use about 20 years ago, but which is now, I believe, abandoned, consisted in saturating the liquor with sulphuric acid in a tank, the sulphuretted hydrogen being carried off to a fire to be consumed, and then evaporating the solution of sulphate in lead-lined open shallow tanks over a fire until the crystallised sulphate was obtained. The result was an evolution of sulphuretted hydrogen during the evaporation, such as gave rise to very loud and grievous complaints. Since that time the method of manufacture has been modified in various ways. The methods that I have seen in use are the following :—

Distillation.

1. In place of adding sulphuric acid directly to the liquor, the practice now is to distil the liquor with or without the addition of lime, and to saturate sulphuric acid with the ammoniacal vapour thus obtained. Various modes of effecting this object are in use in the different works.

The distillation is, in most small works and in some others, effected by introducing the liquor into a closed vessel usually shaped like a boiler, and heating it either by a fire beneath or by throwing free steam into it by means of a perforated pipe at the bottom, or both by an open fire and free steam. Sometimes the steam used for this purpose is superheated, and it is said that in this way the distillation is accelerated. In most works, after as much ammonia as can be obtained in this way has been got off, milk of lime is introduced into the boiler, or the liquor is transferred into another boiler for this purpose, and the heating is continued until all or nearly all the ammonia contained is distilled off. The remaining contents of the boiler are now run or blown out into a tank or pit sunk in the ground, where the lime becomes deposited, while the liquid part either sinks into the earth or is run off into some drain.

In the larger works an arrangement on the principle of the Coffey still, used for rectifying spirits in distilleries, is commonly in use. The principle consists in bringing steam in contact with the liquor as it trickles down inside a tower of about 30 feet in height, provided with some arrangement within for breaking up the stream of liquor and fully exposing all parts of it to the operation of the steam. In the Coffey still used at distilleries there are provided a large number of transverse partitions, which are perforated for the steam to pass through : the liquid to be distilled, run in at the top, is arrested by these partitions, and has to pass by short tubes provided for the purpose from partition to partition from the top to the bottom of the tower. The Coffey still used for distilling gas-liquor is not usually so elaborate as this. There are partitions or shelves, perhaps 60 of them, springing from opposite sides of the tower, and so made as to retain upon them a thin layer of liquor, the excess of which runs over the free edge of one partition to the next partition below it, and so on to the bottom. Sometimes these partitions are dispensed with, and the tower is filled up with broken crockery, stones, or bricks, over which the liquor trickles down, while steam is thrown in at the bottom. Sometimes lime is mixed with the liquor run down the tower, or two towers are used, and in that case the liquor first run down is mixed with lime, and then after due subsidence, run down a second tower. But the best method of using lime is that which I found in use at Illingworth's works at Bradford, at Spence's, Wallace's, and some other of the larger works. The liquor running from the tower passes into a boiler supplied with cream of lime, and heated either by a fire or by steam blown into it. The steam from this, containing free ammonia from the decomposition of the carbonate, is that which is thrown into the tower, and so there pass off by the exit pipe at the top of the tower steam, sulphide of ammonium driven out of the descending liquor, and free ammonia, which pass together to the saturator.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

Saturation.

At some works no lime at all is used in the distillation; but this is wasteful, as a proportion of the available ammonia is thrown away.

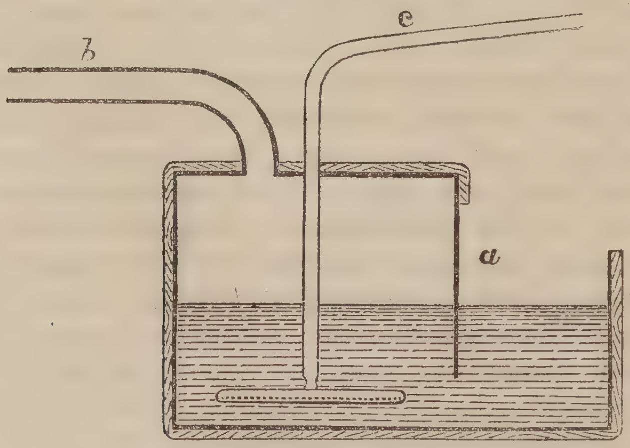
The vessel used to contain the acid into which the ammoniacal vapour is conducted, is called the "saturator." It is differently constructed in different works. The two things which it is necessary to provide for are the complete saturation of the acid, and the carrying off of the liberated gases, the chief of which is sulphuretted hydrogen, in such a way that they shall not be dangerous to the workmen.

a. One form of saturator in common use consists of a closed tank, containing sulphuric acid (chamber acid), to the bottom of which passes from the still a pipe, through some perforations in which the vapours to be decomposed pass into the acid. The gases liberated by the decomposition are conducted away by a pipe from the upper part of the vessel, and are variously disposed of. The vapour continues to be passed in until a sample taken from the tap shows that the acid is saturated. The vapour is then shut off, and the solution of sulphate of ammonia is run off to be evaporated. This evaporation is usually conducted in an open shallow lead-lined trough, at the bottom of which is a steam coil. As the liquor evaporates, the sulphate becomes deposited in a roughly crystalline form. Offensive steam, having an odour like that of an ill-kept pigsty, is given off during the evaporation.

b. Another form of saturator consists of a tank similar to the last, but not completely closed, to which, as the acid becomes saturated, frequent additions of strong sulphuric acid are made through a funnel opening. The gas eliminated is here drawn off by a fan or chimney draught. In this case, as the solution becomes super-saturated with sulphate of ammonia, this salt falls in a crystalline form; and when, in the opinion of the maker, sufficient has thus fallen, the whole contents of the saturator are drawn out hot, by a tap at the bottom, into a tank at a lower level, where, the crystallisation being completed on cooling, the the salt is raked on one side, the mother-liquor being returned to the saturator for another operation.

c. Another form of saturator, commonly termed a "fishing box," is represented in the rough sketch, Fig. 15. It consists of a lead-

Fig. 15.



lined wooden vessel made into two compartments, by means of a curtain of lead *a*, which descends from the top to within about 9 inches or a little more of the bottom, dipping thus into the contained acid. One of these compartments is lower than the other, and is open at the top. The other compartment is close, except that there is a pipe *b* leading from the upper part of it to carry off the steam and liberated gases. The pipe *c* from the still is carried to the bottom of the closed compartment. Strong acid is added from time to time as required. The sulphate falls as it is

formed, and is ladled out with a strainer from the open compartment. So far as I have been able to judge, this is by far the best form of saturator, preventing, as it does most effectually, the escape of the offensive gases given off into the atmosphere of the works. The pipe carrying away these gases, is sometimes carried through a tank of liquor to warm it, or beneath the drying floor on which the sulphate is laid to dry, and thus the waste heat is utilised.

Nuisance.

Sulphate of ammonia works are, if badly conducted, a most intolerable nuisance, in consequence of the offensive sulphuretted hydrogen gas, mixed probably with some offensive hydrocarbons, thrown off into the atmosphere. A very small proportion of this gas, if present in the air, is offensive to the smell; and the nuisance from such works as these may sometimes be perceived at a distance of half a mile or more. It is, moreover, a gas the smell of which is easily recognisable by its peculiarity, and of which the public have always a dread. Hence it happens, perhaps, that when it escapes from such works as these, it is readily traced to its origin, and is fruitful of complaints.

Injury to health.

Medical men are usually ready to certify that the effluvia are injurious to public health, probably referring the effects produced on those who are exposed to their influence in a diluted form, to the operation of the sulphuretted hydrogen as a poison. The public also readily believe that an atmosphere even slightly thus contaminated is dangerous to live in. It is certain that exposure to the diluted effluvia from sulphate of ammonia works does in many persons induce feelings of depression, headache, loss of appetite, nausea or vomiting, and sometimes some oppression of the breathing.

Sources of nuisance.

The sources of nuisance from such works as these may be one or more of the following, viz. :—

1. The reception, transference, or storage of the ammoniacal liquor.
2. The escape of offensive gases and vapours in consequence of leakages about the apparatus. When the fishing box is used such leakages are most likely to occur about the angles and edges of the curtain. I have also known great nuisance to arise from the neglect of the workmen to keep a sufficient depth of liquor in the saturator, by which neglect gas has escaped from beneath the edge of the curtain.
3. Insufficient precautions in disposing of the waste liquor and lime discharged from the still. It is customary to discharge these waste matters while hot, and the vapours that then arise are offensive. In one case at Battersea, which a short time ago attracted a good deal of public attention, it was shown that much nuisance was occasioned by allowing the hot waste to run into the public sewers. People complained of the offensive steam and stinking gases which arose from the sewer inlets in the street, and from the drain inlets of houses communicating with the same sewer. I have heard of similar complaints elsewhere. In the Battersea case it was proved that waste lime also was discharged into the sewer, and that occasionally strong acid was thrown in with the object of clearing away the consequent deposit, giving rise to a dangerous evolution of poisonous gases. When the deposit of waste lime in the settling tank (where one is provided) is disturbed for removal, nuisance is again likely to arise, as also, for a time, from the waste when recently deposited in a heap.
4. The discharge of the offensive gases and vapours liberated in the saturator into the open air. This is the most ordinary of the sources of nuisance from sulphate of ammonia works, and nuisance from this cause has on several occasions caused legal proceedings to be taken for its abatement.

5. The evolution of offensive vapours when the whole contents of a saturator are drawn out into an open tank to cool and deposit the sulphate in a crystalline form.

6. The evaporating down of the solution of the salt drawn from the saturator, when strong acid is not used. Clouds of offensive steam, resembling in odour more than anything else the smell of a congregation of ill-kept pigsties, arise during this process if due precautions are not taken; and in some kinds of locality and in certain kinds of weather this vapour may be a nuisance at a distance of 200 yards or more —indeed, nearly as great a nuisance as the gas evolved from the saturator.

Prevention of nuisances.

As to the remedies for these several sources of nuisance:—

1. The gas-liquor, if about to be made into sulphate within reasonable distance of the gasworks which produce it, may be conveyed to the sulphate of ammonia works by means of underground pipes. If transferred by barge or tank, a similar provision against nuisance should be made as in the transference of gas-tar to tarworks, p. 126. The liquor should be stored in a covered tank, and the opening in the tank should be guarded by a box containing hydrated peroxide of iron, through which the air in the tank may escape when liquor is pumped into it.

2. Care should be taken that all parts of the apparatus are in good condition and tight.

3. For the prevention of nuisance during the running off of the waste matters from the still, the most important point is that they should be thoroughly exhausted of ammonia. It appears to be quite practicable, by careful working, to reduce the ammonia to a per-centage represented by a third figure in decimals. Mr. Steuart, of Clayton, informs me that he succeeds in reducing the ammonia in the liquor operated on to 0·002 per cent.

In discharging the hot waste from the still (whatever kind of still is in use) it should not be conveyed away by an open channel, but by a pipe. The receptacle into which it is conveyed, for deposition of the lime, should be covered, being ventilated merely by a pipe of sufficient length to condense vaporous matter rising through it. The liquid part ought never to be discharged into a drain or sewer with which house drains communicate until it is quite cold. The removal of the lime deposit should be effected as expeditiously as possible, and with all possible precautions against unnecessary exposure to the air. It should be covered up during transmission from the premises, and if shot down in any open place where it is likely to be a nuisance, the surface of the heap should at once be covered with earth patted down upon it.

4. Various means have been adopted to deal with the liberated gases so as to prevent their becoming a nuisance.

a. In some instances, where the conformation of the country has been favourable to this method, the discharge of the gases and vapours from the saturator into a tall chimney shaft has sufficed to prevent nuisance. This is the case at Mr. Peter Spence's works in Manchester. The shaft at these works is 180 feet high, and the vapours meet with flame from the furnace at the point they enter the shaft, and are probably thus in some measure consumed. At Messrs. Bouck & Co.'s works, also in Manchester, I found the vapour discharged inoffensively into a tall chimney shaft 195 feet high, in such a manner that they there came in contact with nitrous fumes discharged into the same shaft from sulphuric acid chambers. Probably in this case the sulphuretted hydrogen became oxidised in part, the quantity thus decomposed varying of course

with the proportion of the two gases present at the same time in the chimney.

b. The favourite method with manufacturers of dealing with the offensive gases is to burn them. Ordinarily this is done by carrying them by a pipe from the saturator into the side of the boiler fire, or into the ashpit; in some works a fire is specially kept up to consume the gases. But before the offensive gases can be burned, they must be dried by condensation of the watery vapour with which they are mixed. I have seen this condensation so much neglected, or performed in so imperfect and slovenly a manner, that the vapours extinguished the fire, and thus rendered the means of abatement of nuisance, commonly supposed to have been provided, nugatory. Various modes of condensation are in use. At some works the pipe which conveys the gases is coiled in a tank of liquor, which it serves to warm up prior to use, or in a tank of water which is destined to feed a steam boiler; or the vapour is condensed by means of an ordinary worm condenser. At the Plymouth Gasworks an 8-inch pipe from the saturator is first carried beneath the floor on which the sulphate is dried, and thence runs along the surface of the ground, where it is bent upon itself, for a distance of about 500 feet, in the course of 290 feet of which it is played upon by jets of water flowing from a perforated pipe above it. At the Stampshaw works the 8-inch pipe from the saturator is first carried round the outside of the building at the eaves, and then enters a worm condenser. At Illingworth's works at Bradford still more elaborate means of condensation are used; but these are very extensive works, a large quantity of sulphuretted hydrogen is made, and, as it is utilised for the manufacture of sulphuric acid, it is very important that the watery and any other condensable vapour should be thoroughly separated. The gases are first conducted into a chamber (in this case an old boiler) through which the pipe conveying the liquor to the Coffey still passes, and they serve thus to warm the liquor; then by a pipe to two iron towers or vertical chambers, divided by partitions springing from opposite sides alternately in such a way as to make a tortuous passage for the vapour; and lastly from these towers through a long series of vertical iron pipes, bent upon themselves in the manner of a continuous condenser (such as is used in gasworks or in the distillation of palm oil, &c.), water being made to flow continually down the outside of the pipes from a perforated waterpipe above. For the most part the sulphurous acid produced by the combustion of the sulphuretted hydrogen is discharged with the fire gases up the chimney, and thus thrown away. At Forbes and Abbott's works at Old Ford, which are very large works, the gases, previously well dried, are conducted not to a fire, but to a small fire-brick chamber, which they enter by a 1 foot square opening, and here, and in a fire-brick flue about 15 feet long, 2 feet 6 inches wide, and 3 feet high, proceeding from it, they are burned by themselves. They are simply ignited, and air is supplied by means of a small circular hole in an iron plate near the entrance of the gas flue into the little chamber. The chamber and flue when I saw them were at an intense red heat. The heat thus generated is used to heat steam boilers. I was told that one boiler had been thus heated for 14 years, and had not received any injury by corrosion from the acid gases. The sulphurous acid after having been used in this way is sent up the chimney shaft.

In carrying out condensation, a nuisance may be occasioned if the condensed liquors are discharged from the condenser hot enough to give off offensive vapours. To obviate this nuisance the condensation should be more perfect than is ordinarily thought requisite. At

any rate the liquids which flow from the condenser should be carried by a pipe to some close receptacle, where they may be cooled before being discharged into a drain where they would be likely to become a source of nuisance. Again, the sulphurous acid discharged from the chimney may cause a nuisance; not so great a nuisance perhaps as the unburned sulphuretted hydrogen would have produced, but still sufficient nuisance to give rise to complaints. Even its discharge from a tall chimney shaft may not suffice to obviate the nuisance in all localities and in all states of the weather. Besides this there is no certainty that the sulphuretted hydrogen is all thoroughly burned when it is thrown into a coal or coke fire. There is reason to believe that sufficient of it to create nuisance often escapes combustion.

c. At Illingworth's Works, at Frizinghall, Bradford, the sulphuretted hydrogen gas, dried in the manner described above, was at the time of my visit being utilised by conversion into sulphuric acid. It was burned in an appropriate flue which, when no gas is being burned (*e.g.* on Sundays), is kept hot by means of a small coke fire; otherwise no fire is needed, all that is requisite being to ignite the gas with a match whenever work is resumed (see Sulphuric Acid Making, p. 172). Mr. Illingworth told me that he was so well satisfied with the result that he was about to adopt the same plan at some works in Leeds. Messrs. Spence and Steuart now have the Bradford works, and are continuing the above practice. The same firm have ammonia works at Birmingham, where the arrangements for burning the gas and making sulphuric acid are similar to those at Frizinghall.

d. In consequence of the difficulties that attend efficient abatement of nuisance by the ordinary mode of burning, I find growing into use in the smaller works a practice of absorbing the sulphuretted hydrogen by passing it, after condensing condensable vapours, through a catch-box or purifier containing some substance capable of arresting the gas. At Mr. Major's Works, at Awsworth, near Nottingham, the agent used is lime. At these works the saturator consists of a lead-lined circular vessel, about 5 feet diameter and 5 feet deep, which is imperfectly and loosely covered with planks of wood. From the back part of the cover an iron pipe passes through the wall of the building to a condenser outside. This pipe is at its commencement 18-inches diameter, but it gradually tapers to 9 inches where it passes through the wall. The condenser is an ordinary worm condenser, and from it the uncondensed gases (and vapour, if any,) pass to a small lime purifier, or "catch purifier," with a cover secured by a water lute, like the lime purifier of a gasworks. A fan is now interposed which serves to draw the vapours from the saturator, and through the condenser and catch purifier, and to drive them to large lime purifiers destined to absorb the sulphuretted hydrogen. There are four such purifiers placed within a separate building. Each is constructed of wood, and is about 18 feet square and 2 feet high, and open. They are each provided with three layers of hydrate of lime laid upon wooden frames so constructed as to permit of the gas passing through them and through the lime laid upon them. At the time of my visit only the top frame had a layer of lime on it 4 inches deep, and although this lime had been in use for a week without being changed, it was still acting with tolerable efficiency in arresting the sulphuretted hydrogen, no smell of which was perceptible outside the building. There was a little smell within the building, but I am satisfied that had the frames been all duly charged even this would not have occurred. In adopting this process in a town, it would be necessary to exercise care lest a nuisance should arise in removing the saturated lime.

A better material than lime for use especially in or near a town is the hydrated peroxide of iron mixed with sawdust. It is acting very well at several works that I have visited. The objection to it is the heat developed during its use. Mr. Major tells me that it was on this account that he used lime, since the wooden frames of the purifier became ignited when he used the oxide of iron. Mr. Close, of Huddersfield, met with a similar accident, but has obviated it by constructing the oxide purifier of brick instead of wood, and by using perforated iron trays to support the material. The size of the purifier or catch-box in use at the time of my visit was 7 ft. 5 in. × 3 ft. 4 in. and 6 feet high. It had three stages, on the lowest of which the material was laid 1 foot thick, and on the other two 4 inches thick. It was open at the top. A fan was interposed between the worm condenser and the box. Similar means of arresting sulphuretted hydrogen are in use at the Beckton Gasworks; the purifier is here very large, and the gas is drawn off from the fishing boxes and driven through the purifier by means of a steam jet. On the whole, too, oxide of iron is a cheap material, since when spent it can be revivified by exposure in the same way as at gasworks, and is valuable for the sulphur it contains when fully spent.

5. Nuisance from the fifth source of nuisance mentioned may be obviated by covering the cooling tank so long as its contents are hot enough to give off offensive vapours.

6. To obviate the nuisance of the offensive vapours given off during evaporation of the sulphate solution, steam should be driven through the saturator for 20 minutes or half an hour after shutting off the ammoniacal liquor. The steam can be carried off and condensed in the usual way.

Manufacture of Sal Ammoniac.

Manufacture of Sal Ammoniac.
Process.

Where chloride of ammonium or sal ammoniac is made directly from gas liquor by decomposition with hydrochloric acid, I have found two methods in use. By the one method, the gas liquor is introduced into a tank or vat, either open or wholly or partially covered, and hydrochloric acid is run in gradually until saturation is complete. By the other method the gas liquor is first distilled with lime, and the acid subsequently added to the distillate; or the vapours from the still, cooled by passing through a long conducting pipe, immersed in water in part of its course, are passed into a close vessel or saturator containing acid, or through a series of such vessels, the gases liberated being carried off to be variously disposed of. The solution of chloride of ammonium is, if the crude gas liquor has been used, now transferred to another tank, or left to stand in the saturating vat for a sufficient time to allow of the subsidence of tarry matters, and is then drawn off for concentration. When distilled gas liquor has been used, this subsidence process is unnecessary, except for the deposition of any sulphide of arsenic present. The concentration of the solution is effected by boiling down in pans or vats by means of a fire beneath, or by a close steam coil within the pan. In works where crude gas liquor is used, a brownish tarry scum rises to the top of the liquor, and most offensive vapours are given off. When the concentration has been carried far enough, the liquor is run off by open channels into shallow cooling vats to cool and crystallise. The crystallised salt is strained off from the mother liquor. In this crystallised state it is used in the process of galvanising iron; but, when it is to be sold as sal ammoniac, it undergoes further manipulation, as follows. The crystallised salt is laid several

inches thick on a long flat platform or kiln heated by fires and flues beneath. This part of the apparatus is either placed within a building or beneath an open shed to protect the salt from wet. After being thus baked for a sufficient time, the salt loses its appearance of being made up of small crystals, and becomes massed into a cake, which when broken across has a fibrous appearance as if it were composed of long thread-like crystals extending from the lower to the upper surface of the cake, of a greyish white colour in the middle, of a yellowish colour on the lower surface, and of a blackish brown colour on the top surface. The discolouration of the top surface is much less marked when distilled liquor has been used in the saturator, and the salt looks altogether cleaner at this stage of its manufacture. A close oven instead of an open-heated platform is sometimes used for baking the salt. The last process is one of sublimation. This is effected in a cast-iron pot lined with fire-brick, and heated by a fire beneath. There is luted on during the sublimation a domed cover having a hole in the top provided with a plug, through which hole watery and empyreumatic matters are allowed to escape, when requisite, by removal of the plug.

Nuisance.

Unless conducted with due precautions, this is a most offensive manufacture, and may create a nuisance for a very long distance around the works. The smell is only to be compared to that from a large congregation of ill-kept pigsties. It is in most respects similar to the smell proceeding from sulphate of ammonia making, but I think is still more atrocious.

Source of nuisance.

Some of the sources from which nuisance may arise are common to this manufacture and that of sulphate of ammonia; such as the reception and storage of the ammoniacal liquor, leakages about the apparatus, and an improper mode of dealing with waste matters. When crude gas liquor is used, the gases and vapours from the saturator are charged most offensively with tarry and empyrematic matters, which render them more disgusting in odour than those proceeding from the modern saturation processes of sulphate of ammonia making. Again, under similar circumstances, the vapours issuing from the pans where the liquor is concentrated, and those arising from the baking of the salt are similarly most offensive.

Prevention of nuisance.

Yet it is quite unnecessary that there should be any offensive vapours. There are none perceptible outside the works of Messrs. Chance, at Oldbury, where sal ammoniac is made on a very large scale from distilled liquor. The modes of preventing nuisances, other than those modes of prevention common to this manufacture and that of sulphate of ammonia, are: 1. The abandonment of the use of crude gas liquor in the saturator, the products of distillation of the liquor being used instead. 2. The careful drawing off, by means of a fan, as at Chance's works, of the offensive gases liberated during the saturation, and the disposal of them inoffensively by one of the modes referred to under the head of sulphate of ammonia making. 3. The careful covering of the concentration pans and the condensation of the vapours. At Chance's Works the pipe that receives the vapours from a long row of large pans is carried through a tank of the liquor to warm it, and at the same time to condense vapours, on its way to a tall chimney shaft. There is no nuisance in Messrs. Chance's Works from the baking of the salt, since the empyreumatic matters, which are present in considerable quantity when the salt has been prepared from crude liquor, are almost entirely wanting.

DISTILLATION OF TAR.

Establishments visited.

Date.	Name.	Locality.	Other Processes or Businesses conjoined.
Nov. 9, 1875 -	Burt, Boulton, and Haywood.	Silvertown -	Manufacture of sulphate of ammonia.
„ 10, „ -	Blott - -	Bow Common -	Do.
„ „ „ -	Grindlay -	Do. -	Manufacture of Brunswick black and railway grease and distillation of resin.
Dec. 22, „ -	Harvey - -	Plymouth.	—
Jan. 11, 1876 -	Burt, Boulton, and Haywood.	Eling, Southampton.	Sulphate of ammonia making, creasoting wood.
„ 20, „ -	Butler & Co. -	Crews Hole, Bristol.	Distillation of resin, manufacture of lamp-black and black varnish.
„ 25, „ -	Hare & Co. -	Bristol - -	Distillation of resin, varnish making, lamp-black making, enamel cloth making.
Feb. 23, „ -	Crow - -	Stratford -	Chloride of ammonium making.
Apr. 28, „ -	Major - -	Wolverhampton.	—
May 5, „ -	Major - -	Awsworth, Nottingham.	—
„ 16, „ -	Metcalf - -	Manchester -	Sulphate of ammonia making.
„ 30, „ -	Maguire - -	Salford -	Do., and soap and cart grease making.
June 2, „ -	Milthorpe -	Wakefield -	Distillation of resin, lamp-black and printers ink making, oil boiling.
„ 4, „ -	Tunstall & Co. -	Newlay, Leeds.	—
„ 14, „ -	Barrow - -	Clayton, Manchester.	Manufacture of sulphate of ammonia and bisulphide of carbon; wood distilling.
„ „ „ -	Bethell - -	Do.	—
Aug. 19, „ -	Butler & Co. -	Upper Parting, Gloucester.	Sulphate of ammonia making.
Nov. 30, „ -	Gasworks -	Lancaster	Do., and gas making.
Dec. 7, „ -	Sadler - -	Middlesborough	Manufacture of carbonate of ammonia and sulphate of ammonia.
Jan. 10, 1877 -	Stampshaw Chemical Works.	Portsmouth -	Manufacture of sulphate of ammonia.
May 14, „ -	Thacker & Co. -	Liverpool -	Do., oil pressing and refining, fat melting.
Oct. 19, „ -	Hardman -	Milton, Burslem	Manufacture of sulphate of ammonia, and sulphuric acid.
„ 24, „ -	Jones - -	Do. -	Distillation of shale.
April 2, 1878 -	Bouck & Co. -	Manchester -	Do., do., and of nitric acid, sulphuric acid, flowers of sulphur, &c.
„ 3, „ -	Hardman -	Clayton, Manchester.	—
„ 9, „ -	Close - -	Huddersfield -	Manufacture of sulphate of ammonia.
May 31, „ -	Mackenzie -	Leith - -	Manufacture of sulphate of ammonia and asphalte.
June 11, „ -	John Millar & Co.	Aberdeen -	Do., do., and of artificial manures and sulphuric acid.

Date.	Name.	Locality.	Other Processes or Businesses conjoined.
June 14, 1878 -	Lime Wharf Chemical Works.	Falkirk -	Manufacture of sulphate of ammonia, shale distilling, manufacture of sulphuric acid.
„ 18, „ -	Alum and Ammonia Company.	Glasgow -	Manufacture of sulphate of ammonia.
July 17, „ -	Hall - -	Redbridge, Southampton.	Do., alum cake, artificial manures, and sulphuric acid.
Jan. 24, 1879 -	Demuth - -	Oldbury.	—
July 9, „ -	Geo. Millar & Co.	Dalmarnock, Glasgow.	Manufacture of sulphate of ammonia and asphalte.

Process of tar distilling.

The processes carried on at tar-works consist in the distillation of coal-tar, and in addition, at many of the larger establishments, the subsequent treatment of the distillates for the preparation of benzole, crude carbolic acid, &c., and the preparation of crude anthracene.

Coal-tar mixed with more or less ammoniacal liquor usually arrives at tar-works in barges, or in close tanks by rail. Sometimes it arrives at the works in casks. It is usually first discharged into underground tanks, and is subsequently pumped up into an elevated store-tank, from which it is run down into the still as required. Old boilers are commonly used in tar-works as storage tanks for tar.

In tar-works there is usually a row of iron stills of a capacity capable of distilling from 6 tons to 20 or 30 tons. Each still is heated by a coal fire beneath, but occasionally "dead oil" (creasote oil) is burned in preference. The whole of the still, crown and all, is covered with brickwork to preserve the heat. The orifice of the still head, from which a bent and tapering neck proceeds, is in the centre of the still, and at one side in the crown is a manhole which is closely fastened down during the distillation. The tar from the tank is run in by a pipe near the top of the still. At the bottom of the still, on the opposite side to the opening of the fire-place, is another opening provided with a pipe and tap, by which the pitch is run out when the distillation is finished. Stills of 20 tons size can be worked off in about 15 or 20 hours, but stills of 30 tons capacity require 40 hours, or perhaps rather less.

The products of distillation are conducted by the tapering neck of the still to a condenser, which is in the usual form of a worm enclosed in a tank of cold water. The exit pipe of this condenser gives issue to a variety of liquids, the nature of which varies with the temperature reached at various periods of the distillation. These are collected separately. The distillation is thus what is termed "fractional." Different means of collecting these products separately are in use in different works, but the products are mostly received first in a "dividing box" or receptacle, from which they are, according to their several densities, run off by separate pipes to store-tanks or receivers usually sunk in the earth, and appropriated to the different products. The liquids which run from the condenser are in order, as follows:—

1st. Light oils, from which benzole and solvent naphtha are obtained. In the earliest part of the process, if (as is usually the case) there be an admixture of ammoniacal liquor with the tar, watery vapour containing sulphide of ammonium comes off before the tar begins to boil. The oils which first come over are termed "light oils," because they float upon water.

2nd. "Heavy oils," or "creasote oils," which sink in water, and contain carbolic acid. These products are usually run off in two portions, the first being "carbolic oil." Naphthaline comes over also in this stage of the distillation.

3rd. "Anthracene oil," which is still heavier than creasote oil: since the discovery of the value of anthracene, this oil has been collected separately.

Up to the time of the running of the anthracene oil no very appreciable quantity of permanent gases comes off, every product being condensable; but with the distillation of the anthracene oil, owing to the high temperature, 200° to 400° (centigrade), permanent gases are formed, consisting according to my informants (Messrs. Burt, Boulton, and Haywood) of about $\frac{2}{3}$ carburetted hydrogen, and $\frac{1}{3}$ sulphuretted hydrogen. When the heat is continued and increased to such an extent as to coke the pitch in the still (a process said to be followed in some works, although I have not seen it), it is said that acrid vapours come off also.

What remains in the still is "pitch." It is hard or soft, according as the production of the heavy oils has or has not been pushed to the full extent short of coking.

In England all the operations of the distillation are performed in the same still, but in Scotland two stills are used. The first distillation is effected in the best works by throwing in free steam, and the products are all condensed together by means of the usual worm condenser. The condensed products consist of the light oils and water containing ammonia. They are received together, and are separated in the usual way by running off the light oil from the top of the receiver and the ammoniacal water from the bottom by means of a siphon. Towards the end of the process the condensed water contains too little ammonia to be worth keeping, and it is then run off into the drains. At smaller works this first distillation is effected by fire heat. The material left in the still is known as "boiled tar," and is run off into a tank, from which other stills are charged, and in these the heavy oils are distilled off in the usual way by means of fire heat. The tar made at the Scotch gasworks furnishes anthracene and carbolic oil in quantities so small that they are scarcely worth separating. The heavy oil, therefore, is usually sent away at once for the "pickling" of timber, and the pitch is either used on the premises at once for making "asphalte," or is run into a bay, and when solid, is sold mostly, I am informed, for the manufacture of artificial fuel, for which it is said to be well adapted.

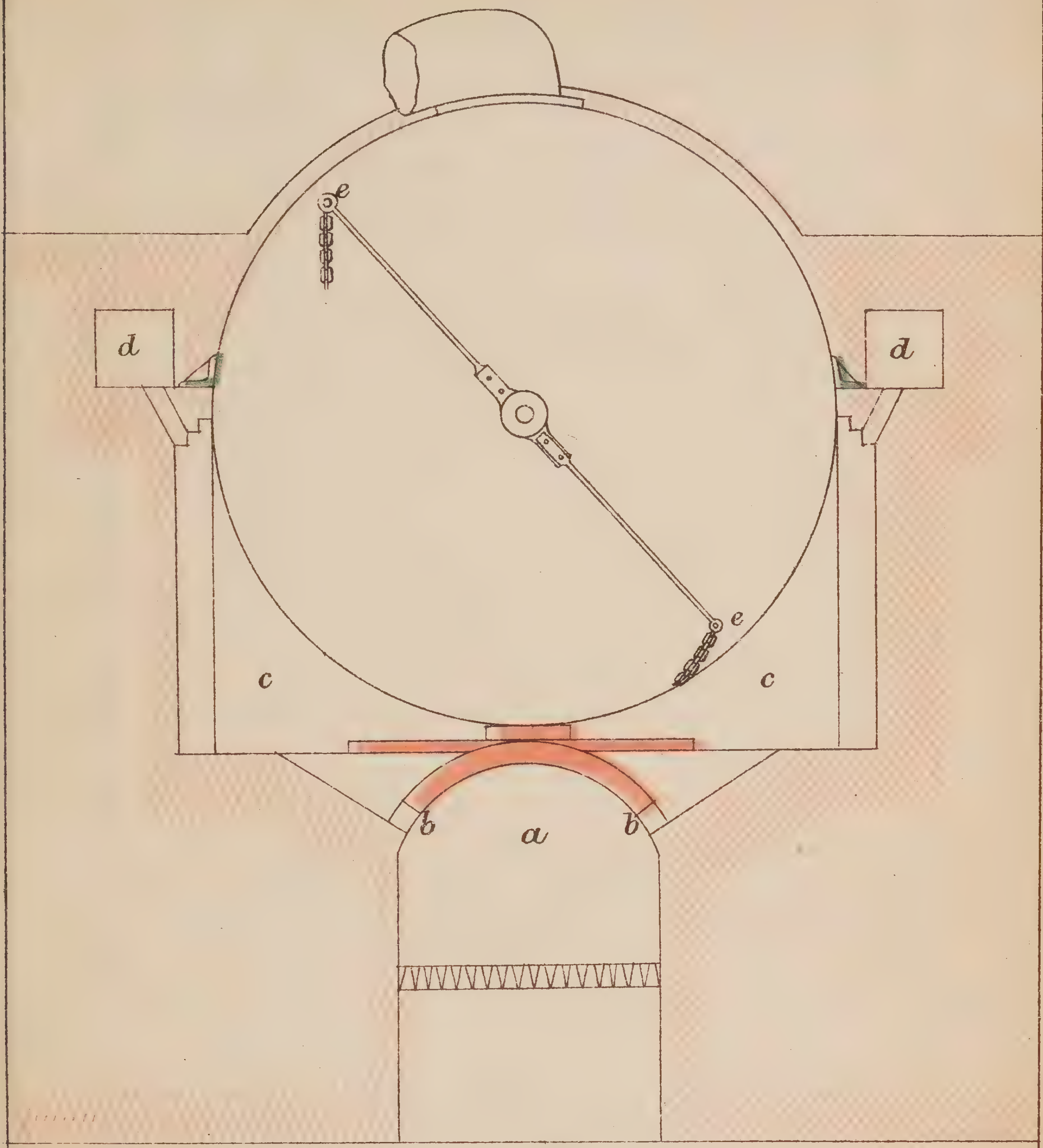
One Scotch tar distillery, namely, that of George Millar and Co., Dalmarnock, Glasgow, demands special mention, partly because the arrangements for distillation differ from those in other works I have visited, and partly because the works are exceptionally remarkable for the perfect neatness, tidiness, and cleanliness, and for the complete freedom from offence with which they are conducted under the admirable management of Mr. Donald. The customary Scotch practice of distilling first with free steam and then with fire-heat is followed, but the boiled tar resulting from the first distillation is not discharged into a tank, but is pumped out through a pipe direct from the first into the second still, so as to avoid any exposure of it to the air, or evolution of disagreeable fumes. And there is this further peculiarity. Mr. Donald has, in common as I understand with some other tar distillers, dispensed with the tar still of the ordinary form, and adopted in its place an iron cylinder about 21 feet long, and 8 feet 6 inches diameter. There are several such cylinders placed side by side in a bank or set. Plate XVI. represents the more essential arrangements of the cylinder. It is

laid horizontally, and its sides are supported by brickwork as shown in the diagram. The heat from the fire *a* does not impinge directly upon the bottom of the cylinder, and although the bottom of the still touches the summit of the arch the still does not rest upon it, but is suspended by stout angle irons resting on fire-brick piers in the side flues. This arrangement, as will be seen from the drawing, while being convenient in case of repairs being required, enables the entire lower section of the cylinder to be well and equally heated. The fire-place *a* is arched along its whole length, and the arch is provided on both sides with openings *b b* (about 20 on each side) through which the heated products of combustion of the fuel pass into a flue or long chamber *c*, running the whole length of the still on both sides between the arch and still. Each chamber communicates by appropriate passages, similar to those in the arch below, with a flue *d* which descends and joins the main flue of the whole set of stills, which main flue leads underground to a tall chimney shaft. In order to keep the bottom of the inside of the cylinder clean, horizontal bars or rods represented in section *e* at Fig. 1, and in elevation in Fig. 2, are made to revolve round and round within the cylinder, at a distance of about 3 inches from the sides, and to these rods are attached, at intervals of a few inches, short pieces of iron chain, which, as the revolution of the rods goes on, drag along the bottom and prevent deposition. The chains are arranged upon the horizontal rods in such a manner that those of the one rod scrape the bottom of the cylinder in the intervals of the course along which it is scraped by those of the other rod. Mr. Donald says that stills thus arranged work for many years without repair. In stills such as this the tar is distilled down to a hard pitch in order to obtain even the small quantity of anthracene oil it will furnish, and the pitch is diluted with heavy oil run into the still shortly before it is discharged. It is at this stage of the operations that the agitating and cleansing apparatus is set to work; it is not used while the distillation is going on. As is the case with the boiled tar, so also the pitch is pumped out from the top of the still, without any exposure to the air, through a close iron trough-like conduit to the pug mill in which it has to be manufactured into asphalte. This conduit is covered with iron plates fastened down, which can be removed however if at any time it should be necessary to cleanse the conduit; but the inclination of the conduit is such that, Mr. Donald says, the pitch has always run clean out of it, and that therefore no cleansing of the conduit has ever been required. If pitch is wanted, it is pumped into a close cylinder to cool before it is run out into the pitch bay. I cannot speak too highly in praise of these model works.

Usually the pitch, after being allowed to stand for some hours in the still after the fire has been raked out, is run off first into a closed receptacle termed the "pitch-oven," or "pitch-cooler," where, if the distillation has been carried to the extent of making hard pitch, the pitch is softened by adding to it, through a pipe which enters the oven from a reservoir, as much creasote oil as may be necessary to bring it to the physical condition of soft pitch; but at some works the oil is added before the pitch leaves the still. In this oven it is left to cool still further. The form of the pitch-oven varies. Very commonly an old boiler is used for this purpose. At Burt, Boulton, and Haywood's works at Silvertown, the pitch-oven is in the form of a boiler, and is made of $\frac{5}{8}$-boiler plate. The manager, Mr. Bernays, tells me that the pitch is retained in the stills for 30 or 40 hours, and in the pitch-oven for 12 hours; but the actual and relative time during which it is retained in either the still or the pitch-oven vary in different works. At other works the pitch-cooler is a quadrangular close chamber of brickwork,

ARRANGEMENT OF CYLINDER USED FOR TAR-DISTILLING AT G. MILLAR & Co WORKS.

Fig 1.



Scale, ½ inch — 3 Feet.

Fig 2.

Scale, ½ inch to one Foot.

DANGERFIELD LITH. 22. BEDFORD ST COVENT GARDEN.

varying in size according to the extent of the works. At Demuth's Works at Oldbury, the pitch is run from all the stills by means of an underground pipe into a series of vaulted cooling chambers, each about 80 feet long by 15 feet wide, and 15 feet high, and it is passed from one to another as it cools by means of openings, provided with shuttles, near the floor.

After remaining a sufficient time in the cooler or pitch-oven, the pitch is run off either into a broad, shallow excavation usually lined with bricks, called a "pitch-bay" to solidify, or into tubs. Sometimes it is not at once tapped off from the cooler into the tubs, but first into a dipping-tank from which it is ladled into the tubs.

When anthracene oil is left to stand, a solid crystalline-looking matter separates from it. This is crude anthracene. It is separated from the anthracene oil by straining, sometimes upon a layer of canvas stretched upon a frame, or in an open pan provided with a false bottom, the filtration being assisted by the use of an air pump, but more usually by straining through long canvas bags; and it is then subjected to pressure in a screw or hydraulic press. In some tar-works it is partially purified by dissolving the pressed material in naphtha by steam heat, and then running the solution into shallow vats to crystallise. The crystalline mass is again pressed, or is first subjected to the action of a centrifugal machine and then pressed, the removal of the last of the naphtha being assisted by throwing steam into the press.

The other oils are subjected to various processes of redistillation and rectification for the obtaining from them of such substances as benzole, solvent naphtha, carbolic acid, &c. I shall refer to these processes in another section of my Report. (*See* pp. 151 and 156.)

Nuisance.

The effluvia from tar-works are sometimes a very considerable nuisance, not only in their immediate neighbourhood, but even at a distance of half a mile and more. The vapours from hot pitch will travel as a compact white cloud near the surface of the ground to great distances. To some persons they are intensely disagreeable. The only ill effect upon health that I have heard of, however, is that they produce in some persons headache, giddiness, faintness, nausea, and perhaps some oppression of the breathing, but never anything very serious, or permanent ill effects.

Sources of nuisance.

The following are the ordinary sources from one or more of which nuisance may proceed:—

1. The reception of the tar in uncovered barges, and its transference to the tanks or storage receptacles at the works. The offensive odour is chiefly that of sulphide of ammonium.
2. The escape into the atmosphere of offensive uncondensed and non-condensable products of the distillation. The offensive gases chiefly come off at the close of the distillation.
3. The escape of a more or less dense white vapour when hot pitch is run off from the still or pitch-oven into the pitch-bay, or a similar vapour from the pitch-bay or tubs before they cool.
4. The escape of offensive vapours from the pitch-oven.
5. The combustion of creasote oil as fuel for the stills, when the arrangements for its proper combustion are incomplete.

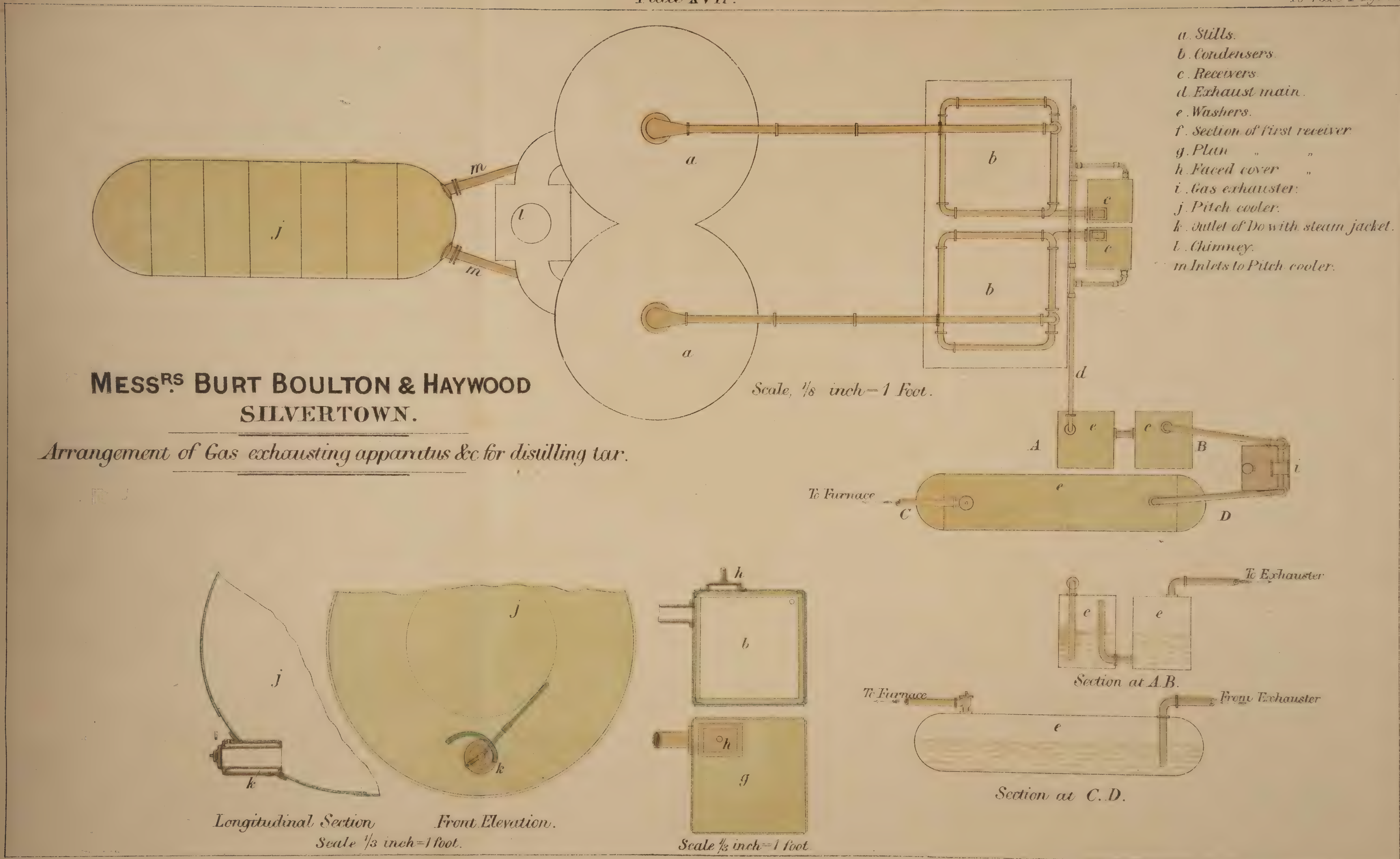
Prevention of nuisance.

As regards the methods of preventing these nuisances:

1. Tar should always be conveyed to tar-works in air-tight vessels, so as to obviate the escape of effluvia during the transit. Barges require to be specially constructed for this purpose, and the part which contains the tar should be covered down with an air-tight cover (*See* Gas-making, p. 127.) During the pumping the cover should be no further open than may suffice for the pipe to pass in. The reservoir at the

works should also be covered, and the air which passes out, as the tank is filled, should be made to pass through a box containing hydrated oxide of iron for the absorption of any sulphuretted hydrogen that may issue.

2. The nuisance arising from the discharge of offensive gases and vapours during the distillation is to be obviated by the adoption of means to collect these gases, and to condense such as are condensable, and to burn such as are combustible, or otherwise to deal with them chemically. Sometimes, however, the nuisance arises from leakages about the still, or from insufficient means of condensing the products of distillation which it is important to collect. In the latter cases the remedy is obvious. At Crow's Tar Works at Stratford the exit-pipe from the condenser is bent into the form of a siphon, from the upper part of which the vapours which are uncondensed are carried by a long pipe to the fires beneath the stills, and are there consumed. A similar arrangement, but more perfect, is in use at Demuth's Works at Oldbury. Just prior to the pipe from the condenser reaching the dividing box it is bent down into a long siphon, and at the part of the pipe about the commencement of the siphon a pipe leads away the gases to a large brick chamber of the same capacity as one of the tar-cooling chambers, and having in it two shelves covered to the depth of 8 inches with a mixture of sulphate of iron and slaked lime. There is a tap placed on this tube and another tap in a pipe leading down from the bottom of the siphon, by which pipe the siphon may be emptied of its contents when necessary. At Hall's Works at Redbridge the pipe to convey away the gases springs from the dividing box itself, and leads to a box containing two perforated trays, on which a layer of sawdust mixed with oxide of iron (made by precipitating sulphate of iron with lime) is placed. The dividing box is closed with a movable cover, which is supposed to be kept down during the process of distillation of the tar. This is not so good an arrangement as that at Demuth's, since it is too much under the control of the workmen. Indeed, on the occasion of a visit I paid to these works, while distillation was going on, I found that the workmen had removed the cover, and had not replaced it. At Messrs. Bouck & Co.'s Works at Manchester, the dividing box is closely covered with an iron hood, from the top of which a pipe conducts the non-condensable gases into the chimney of the works. The nitrous fumes, not condensed, from the manufacture of nitric acid and the waste gases containing nitrous fumes from the vitriol chambers (no Gay-Lussac tower being in use), are thrown into the same chimney, and thus the sulphuretted hydrogen gas is decomposed, oxidised, and rendered inoffensive. But the most perfect arrangements for preventing nuisance from uncondensed and non-condensable vapours and gases that I have seen are at Messrs. Burt, Boulton, and Haywood's Works at Silvertown, near the Victoria Docks. This firm has obligingly favoured me with an account of their process, and with plans (Plate XVII.) of their apparatus for avoiding nuisance in working. From each condenser the condensed and uncondensed matters pass into a receiver having an opening at the top, which is firmly closed down, during working, with an accurately-faced iron cover. Out of this receiver the condensed liquids are drawn off below to the store tanks, while the uncondensed gases and vapours are drawn off above by an air-pump or gas-exhauster, worked by a small steam-engine provided for the purpose. These gases and vapours from all the whole row of receivers pass into an exhaust main, which communicates with two "washers," the first arranged like a chemist's Woulffe's bottle. They have to pass through both of these, where a certain amount of further condensation takes place. They then pass through the exhauster to a third condenser or "washer," shaped like a boiler; and here again they have to pass through water and over water



Dangerfield Lith. 22, Bedford St. Covent Garden.

for some feet, to the discharge pipe, which conducts such as are still uncondensed to a fire, where they are consumed. This exhausting arrangement has the further value of assisting to draw off the products of distillation from the still, and to clear this of offensive gases, which would otherwise escape into the air during the process of recharging with tar. Another advantage which these manufacturers say they thus obtain is, that the watery vapours (containing sulphide of ammonium) which accompany the naphtha and benzole series of products, and which were formerly wasted, are now collected and utilised for the manufacture of sulphate of ammonia. The benzoles also themselves are increased in bulk from the greater care with which these lighter vapours can be collected. Further, by the use of the air-pump and the closed receiver, the duration of the whole distilling operation is abridged very sensibly, which is itself a great source of economy in a large manufactory.

3. The source of nuisance arising from the pitch vapours, when the hot pitch is run off, is now much obviated in most works (but by no means in all, especially small works) by the use of a pitch-oven or cooler. When it is run out from the pitch-oven, the pitch is said to be at a temperature of 200° to 250° (Fahr.), and but little vapour is then given off. Messrs. Burt, Boulton, and Haywood inform me that there is this advantage in retaining the pitch as long as possible in the cooler, in addition to the avoidance of nuisance, viz., that the oily vapours become condensed, and incorporate themselves with the body of the pitch, which thus is increased in value as well as in bulk, since the softer the pitch can be produced, the higher the price it obtains. Finally, whatever conduces to the free running of the pitch from the still or along the conduits or channels from the "pitch-oven" to the "pitch-bay," tends to lessen nuisance by reducing the temptation to run off the pitch from either of them at too high a temperature. The dilution with creasote oil within the still itself, instead of within the cooler, has this good result, that more of the cooling can be effected while the pitch is shut up within the still. If the temperature is too low, the pitch will not run well along the channel to the pitch-bay. Sometimes, when the pitch has been kept too long in the pitch-oven, the discharge-pipe becomes choked, and in such case the workman usually clears it with a red-hot iron. Now and then this proceeding has given rise to explosion. At Burt, Boulton, and Haywood's, the necessity for this is obviated by enclosing the discharge-pipe in a steam-jacket; but the pitch is in truth often run out at a temperature at which it gives off abundant vapours. Hence, there is an advantage in having the bay not too far from the cooler, and in the channels being properly constructed in brick or stone, and provided with movable covers all along their course; any vapours are thus prevented escaping during the passage of the pitch, and the pitch itself is less likely to cool in the channels, as it is apt to do in a long open channel, and thus to choke it up, and to delay the discharge from the oven which is cooling all the time the pitch is running from it. A further advantage is gained by constructing the bay in partitions, which may be filled in succession, instead of running into one large bay at once, since the pitch cools quite as rapidly, while a less surface is exposed from which vapour may escape. This is the arrangement at Burt, Boulton, and Haywood's Tar Works at Eling, at the head of Southampton Water. Here the pitch is run from the pitch-oven by a brick channel about 2 feet square (lime-whited within, for facilitating the picking out of any pitch which may chance to solidify), and covered along the whole course with boards, a distance of about 17 feet, and with a fall of about 1 foot in that distance to the pitch beds. These are constructed

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in brickwork in a series of rectangular tanks or beds, so arranged as respects the channel that the pitch from the latter may be delivered into any one of the beds at pleasure. These beds are covered with boards, similarly to the channel. At Messrs. Bouck & Co.'s Works, the pitch bed, which is close to the "cooler," is entirely enclosed within an erection or house of galvanised iron. The sides of this are constructed with movable panels or shutters. Any accidental issue of vapour from the chinks is obviated by hanging curtains of sacking over the tops of the movable panels. This has proved an effectual mode of preventing nuisance from the pitch-bay. A similar arrangement has been made on the new works of Mr. Hardman at Clayton. The nuisance that arises during the filling of tubs from the pitch-cooler is obviated, in a measure, at Hare & Co.'s Works in Bristol by filling the tubs within a closed shed.

4. I have described the "pitch-oven" as a closed receiver, but it is clear it cannot be entirely closed, or the pitch could not run in. It must have a vent somewhere at the roof. It is a common practice to leave this vent open to the air, but then foul and offensive gases escape into the atmosphere. At Mr. Metcalf's Works, in Manchester, a 12-inch pipe rises at an acute angle from the pitch-oven, and is carried a distance of about 30 feet to a chimney-shaft, 60 or 80 feet high. Liquid matter condensed in this pipe runs back into the oven. At Bouck & Co.'s Works the relief-pipe from the upper part of the cooling chamber is bent down into a vessel of water outside, into which the end of the pipe dips about an inch.

5. The nuisance from the burning of creasote oil in the furnaces arises out of its imperfect combustion, and the formation of smoke having an acrid irritating odour. The remedy for this is the use of an apparatus properly adapted for the purpose, and its careful management. One apparatus of this kind, which has appeared to me to answer perfectly well, and, when I saw it in use at Crow's Tar Works at Stratford, was burning a hydro-carbon oil without producing smoke, was patented by Mr. Crow (June 25, 1867, No. 1846). A description of it may be seen in the "Mechanic's Magazine" of January 3rd, 1868.

THE "DIPPING" OR VARNISHING OF IRON PIPES.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
June 17, 1878 -	Phœnix Iron Foundry.	Glasgow -	Casting iron pipes, &c.
„ 19, „ -	MacDougal, Stevens, & Co.	Ditto - -	Ditto.
„ „ „ -	Kerr & Co. -	Ditto - -	Ditto.
July 9, 1879 -	Ditto -	Ditto - -	Ditto (second visit.)
„ „ „ -	Laidlaw & Co. -	Ditto - -	Ditto.

Process.

In order to preserve cast-iron pipes they are covered inside and out with a black varnish. For this purpose a mixture of coal-tar and creosote oil is used, the latter being greatly in excess in order that due liquidity of the mixture and rapid drying of the varnish may be ensured. A vertical cylindrical vessel, open at the top, of a height sufficient to receive pipes of the length to be dipped, and some feet over, is used to contain the dipping mixture, and it is heated by a fire

beneath. A number of pipes bound together by a chain are by means of a crane let down lengthwise into the hot mixture, left there about half an hour, and then raised out of it again and laid down on their sides to cool and for the varnish to set.

Nuisance.

In this process an abundance of offensive vapour (ultimately all the vapourisable constituents of the mixture) is given off, creating a considerable nuisance to the surrounding neighbourhood. The amount of vapour given off may be judged of by the fact that at one large establishment I was informed that from 6,000 to 7,000 gallons of the mixed material were used per month. The vapour is complained of as irritating to the respiratory organs, and as causing headache, sickness, &c.

Prevention of nuisance.

At MacDougal, Stevens, & Co.'s works an attempt has been made to reduce the nuisance in the way represented by the following rough

Fig. 16.

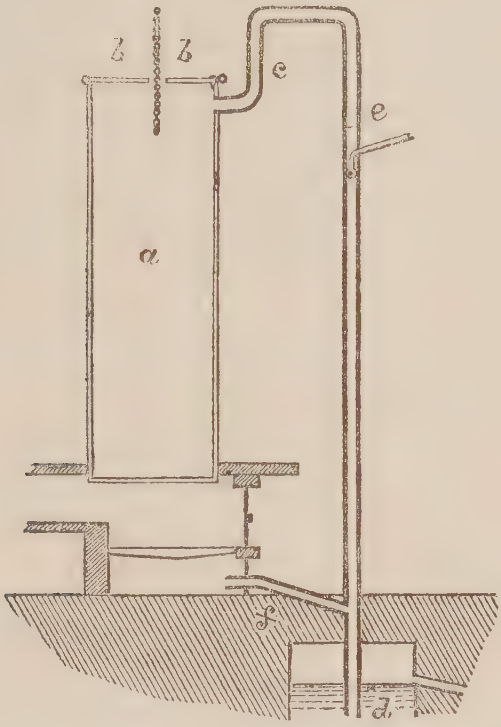

diagram. The top of the dipping vessel *a* is covered by a pair of plates *bb* which, when shut down, close in the vessel, leaving only a hole in the middle occupied by the chain that supports the bundle of pipes. From below this cover a pipe *c* issues in the manner represented, and is carried down into an underground tank *d*. In the upper part of this descending pipe is a diaphragm of wire gauze *e* of 60 holes to 1 inch, and just below it a fine jet or spray of water plays into the pipe, and condensing the vapours which pass down it, flows into the tank below, carrying the condensed matters with it; here they separate from the water and are collected. Just before the descending pipe enters the tank a branch *f* passes off to the ashpit of the fire which heats the dipping vessel. To prevent nuisance during the time that the covers are necessarily open for the introduction or removal of the pipes, and to obviate the nuisance arising during the cooling of the pipes, the whole operation would have to be conducted within a closed building lofty enough to admit of the hoisting machinery moving with sufficient freedom.

THE MANUFACTURE OF ARTIFICIAL OR "PATENT" FUEL.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other businesses or processes conjoined.
June 27, 1878	Cory and Yeo -	Swansea.	—
July 1, 1879	John Hall, Junr.	Sunderland -	Tar-distilling.

Process.

The above two establishments are the only establishments I have been able to see at work. Others up the Swansea valley were not at work when I visited that locality. The materials used in the manufacture of "patent fuel" are coal dust and coal-tar pitch. The Scotch pitch answers well for this purpose, the tar not being distilled to so hard a pitch as in the case of English tar, inasmuch as it is rarely considered worth while to extract from it the small amount of anthracene oil which it contains (see p. 139). But in order to adopt English pitch for patent fuel making it is requisite to soften it by the addition of heavy or creosote oil. This addition is made at the tar-works (p. 143). Small coal or "slack" received at the works is sifted, so as to separate the pieces of coal from the dust, the former being used as fuel for the furnaces. The pitch is crushed by passing it between a pair of fluted rollers. The coal dust and the crushed pitch are now elevated separately by means of a "Jacob's ladder" (or endless band with little scoops or buckets affixed to it) to a platform above, where they are fed, in definite proportions, into the top of the mixing apparatus. The mixer is a vertical cylinder of iron about 8 feet high and 3 feet wide, having in the centre a revolving shaft or axis provided with arms and made to revolve by gearing at the top. This apparatus is open at the top. As the shaft revolves steam is thrown into the lower part of the cylinder, and its effect is to soften the pitch and to damp equably the mixture of pitch and coal dust. The mixture passes out from the lower part of the mixer in the form of a soft damp powdery material. At Cory and Yeo's works this material is received upon an iron plate, from which by means of appropriate machinery it is swept into moulds arranged round a circular horizontal revolving table and kept constantly wetted with water. Each time a mould is filled a stamper comes down and compresses the material into a brick. The brick of patent fuel thus made is lifted out of the mould by ingenious machinery as the table revolves, and is transferred to an endless band, by means of which it is carried away to be stacked.

At Hall's works the moulding and stamping are effected by an apparatus which works in a horizontal direction, and not in a vertical direction as at Swansea. The mixture falls from the cylindrical mixer into a circular pan from which the stamper is fed, and in order to cool the mixture in this situation a blast of cold air is thrown upon it.

During the process above described an abundance of steam mixed with vapour of tar oil, and smelling strongly of this offensive substance, passes off from the open top of the receiver, and, escaping through the louvred roof of the shed or building in which the work is carried on, may become a source of nuisance to the neighbourhood. There can be no doubt that it might easily be arranged to draw off the steam and offensive tar oil vapour as they issue from the top of the receiver, and to condense them or otherwise dispose of them so as to avoid nuisance.

MANUFACTURE OF "ASPHALTE."

ESTABLISHMENTS VISITED.

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Establishments visited.

Date.	Name.	Locality.	Other Processes or Businesses conjoined.
May 14, 1877 -	Atkins & Co. -	Pumpfields, Liverpool.	—
„ 31, 1878 -	Mackenzie -	Leith - -	Tar distilling. Manufacture of sulphate of ammonia.
June 11, „ -	John Miller & Co.	Aberdeen -	Tar distilling. Manufacture of sulphate of ammonia and artificial manure.
July 9, 1879 -	Geo. Millar & Co.	Dalmarnock, Glasgow.	Tar distilling and manufacture of sulphate of ammonia.
„ „ „ -	British Asphalte Company.	Port Dundas, Glasgow.	Ditto ditto.
„ „ „ -	Neilson & Co. -	Glasgow -	—
„ „ „ -	Glasgow Asphalte Company.	Greenshields, Glasgow.	—

Process.

Where tar is distilled, pitch is run, or, at G. Millar & Co.'s works, pumped directly from the tar still into a pug mill, where it is intimately mixed up with sand and sometimes also with chalk. From this mill, while still liquid, the mixture is run off into sand moulds to solidify. Where tar is not distilled, as at Atkin's works, the pitch is first melted in an open iron tank, and the other materials are then added and mixed with it. Other pitchy and bituminous matters are said to be sometimes used as well as pitch.

Nuisance and mode of prevention.

During the whole process, until the completed asphalte becomes cool, offensive vapours are given off. In order to prevent public annoyance, J. Miller & Co. have covered their pug mill, and a pipe conveys the vapours given off into the chimney stack of their works. At Neilson & Co.'s works, where the sand is mixed by hand with the pitch in the pot in which the pitch is melted, a conical iron hood is suspended over the pot by a pipe which passes up into a chimney 60 or 70 feet high; the space between the edge of the hood and the pot is enclosed by sacking, which can be opened at certain places as requisite for the manipulation. The fumes discharged from the chimney create no nuisance. Where a sufficiently high chimney is not available, the pipe should lead first to a scrubber, and if necessary, a fan should be used to draw off the vapours. The cooling should be effected in a closed building, which might if needful be similarly ventilated.

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Establishments visited.

MANUFACTURE OF LAMP-BLACK.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 22, 1875 -	Shackell and Edwards.	Islington -	Printers' ink making, oil boiling.
Jan. 20, 1876 -	Butler - -	Crews Hole, Bristol.	Distillation of resin and black varnish making.
" 26, " -	Hare & Co.	Bristol - -	Distillation of resin, varnish and enamel cloth making.
Feb. 23, " -	Smith - -	Stratford -	Distillation of resin.
" " " -	Buntervell -	Ditto.	—
June 2, " -	Milthorpe -	Wakefield -	Distillation of resin and printers' ink making.
Jan. 10, 1878 -	Stampshaw Chemical Works.	Portsmouth -	Tar distilling. Manufacture of sulphate of ammonia.
April 4, " -	J. Barrow -	Gorton, Manchester.	Manufacture of black varnish.
May 31, " -	Fleming & Co. -	Granton, Edinburgh.	Resin distilling, oil boiling, printers' ink making.

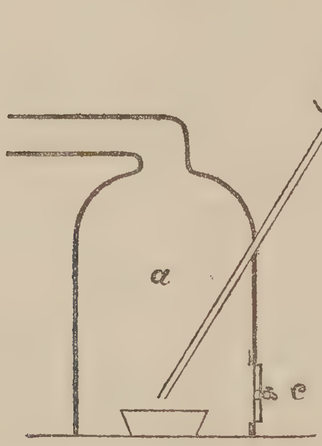
Process.

The materials generally used are some of the coarser and less valuable products of the distillation of tar or resin. Creasote-oil is the material which appears to me to be used most frequently.

The process is a very simple one. The material is burned in such a way and with such an imperfect supply of air as to produce as much smoke as possible, which is conducted by a flue to a large chamber where the soot is deposited and accumulates.

The subjoined rough sketch represents the sort of apparatus generally used for burning the liquid hydrocarbons employed. It consists of a small

Fig. 17.



chamber *a*, through the side of which a pipe *b*, funnel-shaped at the top passes: through this pipe the material is allowed to dribble, and beneath the lower end is a pan to catch what falls from the end of the pipe, and here the material is burned. From this little chamber an iron pipe or short flue conducts the smoke into the black-house. The chamber has a little door *c* at its lower part, and in it is an aperture for the admission of air in small amount to support the combustion. When a solid hydrocarbon, such as naphthaline, is burned, it is laid in a pan at the bottom of the little chamber. The precise form and arrangement of

this burning chamber varies in different works. There are usually several burning chambers, either arranged within a closed room or beneath a shed in the open air. Another sort of burning arrangement is typified by the following rough sketch of that in use at the Stampshaw Chemical Works.

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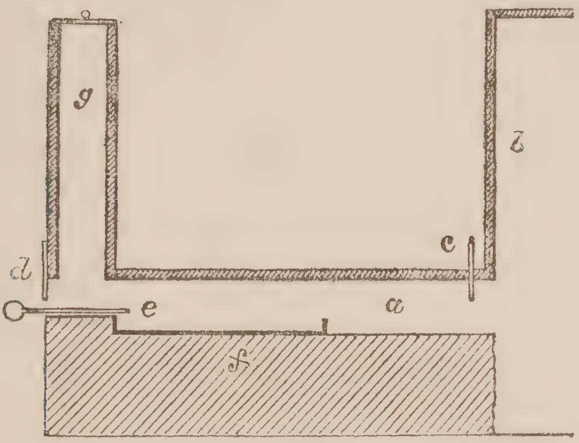
On Effluvium Nuisances, by Dr. Ballard.

Fig. 18.



At these works a horizontal brick flue *a* about 18 inches square and about 10 feet long, is provided. At one end it enters the black-house *b*, and is here provided with a damper *c* to shut it off when not working. The other end opens to the air, and here is a sliding door *d* which, when shut down, leaves an opening round a small pipe which enters in this situation from a main pipe that conveys creasote oil in a similar manner to four burners of this description placed side by side. At the bottom of the flue is an iron tray *f* to catch any liquid that falls from the tube, and in this tray the oil is burned. The burning of oil in one of these flues is not allowed to go on for more than three hours, and, when the combustion is over, the communication with the black-house is closed, the entrance door of the flue opened, and the cover taken off the chimney *g* so that the flue may become cooled, and another flue is taken into use.

The black-house is a brick chamber into which the smoke passes, and where it deposits its sooty particles. In some works there is only one undivided chamber ; in other works there are more than one, and the chambers communicate by flues through which the smoke passes from one to another. At other works the chamber is divided by vertical partitions springing alternately from the two ends so as to constitute one high zig-zag flue, along which the smoke must travel to its outlet from the black-house. This chamber must needs have an opening somewhere to the outer air. The opening is sometimes a small chimney in the roof, and sometimes a short louvre tower. This is necessary to produce a trifling draught, just enough to carry the smoke into the chamber and no more.

Calcination of lamp-black.

In some works, the black from the black-house is also calcined, the object of the "calcination" being to get rid of all greasiness, a point of great importance when the lamp-black is to be used for making fine kinds of printers' ink. This process is conducted in circular iron pans, usually about $2\frac{1}{4}$ feet high and $2\frac{1}{4}$ feet diameter, which are provided with removable iron covers. A pan of this size will hold about 2 lbs. of lamp-black. A bowlful is first put in and lighted by a red-hot iron, and more and more is added from time to time as the ignition proceeds. When the pan, being full, leaves off smoking, the calcination is known to be complete, and the pan is then covered and its contents are allowed to cool. The loss undergone in this process is

about 25 per cent. The smoke which comes off is acrid and very irritating to the eyes, like that proceeding from boiling oil, and it is difficult for a person unaccustomed to it to remain many minutes in the chamber where calcining is going on. This process is sometimes conducted within a chamber, as at Shackell and Edwards in Islington, but frequently under a shed or even in a building freely open to the air.

Nuisance.

There are three sources from which nuisance may arise in lamp-black making: 1. The smoke which issues from the chimney of the black-house, small as it sometimes is, often constitutes a nuisance to near neighbours; but the nuisance is not a very serious one, and it does not extend very far from the works. I have not heard it complained of at a greater distance than about 50 yards. The odour, even when but little smoke escapes, is oppressive and suffocating in character, and resembles that diffused in a room by a smoking table-lamp. I have known people to say that it occasions headache, but I never heard it stated that it has been otherwise injurious to their health. 2. A similar nuisance of suffocating smoke sometimes proceeds from the burners, but this is when they are leaky or when there is a deficiency of draught through the black-house, or when the doors of the burning chambers do not shut closely, and when there is much wind blowing past them. I have noticed this nuisance chiefly when the burners have been open to the air and merely protected by an open shed. 3. The escape of acrolein and other offensive vapours from the calcining house.

Prevention of nuisance.

The best mode of preventing nuisance from the black-house is so to elongate the chamber as to give abundant opportunity for the soot to deposit in the course of the smoke along it to the outlet, and by taking means to consume by fire what little smoke escapes deposition. The most effectual arrangement for the accomplishment of these ends that I have seen is at Butler & Co.'s tar-works, Crews Hole, Bristol. The black-house is 150 feet long, and is so divided by partitions within as to cause the smoke to traverse a distance of altogether 500 feet before it finds an exit. The exit from the chamber communicates with a fire in which the last of the smoke is consumed, and which serves to assist in regulating the draught through the chamber.

The regulation of the draught through the burner and black chamber is of importance in order to avoid the escape of smoke from the burners. If the draught be too great, too much black is lost from the chamber, but if, on the other hand, it be too little, the smoke instead of passing into the chamber will come out into the works and create a nuisance. I have known this to occur, especially where the burners have been erected in the open air, under circumstances in which variation in the force of the wind could not fail to interfere with due regulation of draught. This part of the manufacture should be conducted within a building of some sort.

The best mode I have seen of preventing nuisance from calcination is in operation at Shackell & Edwards, printers' ink works, in Hornsey Road, Islington. At these works the black is calcined in a chamber 20 feet square and 25 feet in greatest height, with a paved floor and arched roof. In the centre of the roof is the opening where a fire was formerly placed, but which is now closed by a sky-light, capable of being raised. The calcining pots are ranged round this chamber, and a fan, employed to draw off the vapours from the oil-boiling pans, is further utilized to draw off also, from the upper part of the calcining-house, the vapours arising from the calcination, and to drive them into the boiler fire where they are consumed. Calcination should always be conducted in a closed building duly ventilated so as not to create nuisance.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

THE MANUFACTURE OF CARBOLIC ACID.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 20, 1876 -	Storey - -	Lancaster -	Manufacture of picric acid.
Mar. 26, 1878 -	Bowdler and Bickerdicke.	Church, near Accrington.	—
„ 27, „ -	Charles Lowe & Co.	Reddish, near Manchester.	Ditto.
„ „ „ -	Calvert & Co. -	Bradford, Manchester.	—
April 2, „ -	Bouck & Co. -	Manchester -	(Crude acid.) Tar distilling.
Jan. 24, 1879 -	Demuth -	Oldbury -	(Crude acid.) Tar distilling, &c.
Feb. 27, „ -	Longshaw and Sons.	Sankey Bridge, Warrington.	Manufacture of picric acid.
May 13, „ -	Corbett & Co. -	Cefn, North Wales	Manufacture of picric acid and nitric acid.
„ „ „ -	Graicher -	Ditto - -	Ditto.
June 5 „ -	Gaslight and Coke Company.	Beckton, North Woolwich.	(Crude acid.) Gas making, tar distilling, &c.
At various times	Various tar distillers.	- - -	(Crude acid.)

Process.

The source from which carbolic acid is obtained is the "carbolic oil" obtained in the distillation of coal tar. Sometimes it is sent away from the tar works in this condition, but at some works the crude acid is prepared from it, and sent away to special works for refining. Carbolic oil contains carbolic and cresylic acids mixed with other light and heavy oils in varying proportions, and it is to separate them from these oils that the first process is designed. The carbolic oil is first treated in an iron tank with caustic soda, which dissolves out the carbolic and cresylic acids. This solution is siphoned off into an open tank lined with lead, where sulphuric acid is added; this combines with the soda, and causes the separation of the crude carbolic acid, which is then ladled or siphoned off. The mixture of light and heavy oils left from the soda solution is of value, and is distilled fractionally, as described at p. 156, for the preparation of benzole, &c. The solution of sulphate of soda from the acid tank, which is more or less acid in reaction, is run off into the drains.

Carbolic and cresylic acids are prepared from the crude acid by a series of fractional distillations and crystallisations. For these distillations iron stills, capable of dealing with charges varying from 150 to 500 gallons, are used; and they are heated by a fire beneath. The crude acid is transferred from the casks in which it arrives at the works to a closed tank, preferably sunk in the ground, from which it is pumped into the still, which has a man-hole in the roof and a neck from which a pipe leads to a worm condenser. The residue of the first distillation, which is or ought to be conducted to dryness, is a light and spongy coke, which, when the still is cool, is broken up with an iron bar and removed through the man-hole. It is used as fuel. During the last part of this first distillation offensive uncondensable gases are given off. When, in subsequent distillations, an acid is distilled off which solidifies at a higher temperature than that which results from the first distillation, the product is apt to solidify in the pipe, and hence the pipe leading to the condenser is provided in its course with a short-necked opening, capable of closure, through

which hot water may, if necessary, be introduced to clear the pipe. The products of condensation are collected in numerous small fractions, and are usually received in a series of galvanised iron vessels, which are left open during the process of their filling, but covered with a lid when they have become full. It is said that it is necessary they should be open in order to allow of the process being watched so as to prevent overflow. Carbolic acid is most abundant in the earlier fractions and cresylic in the later fractions. The vessels containing the products of distillation are then set aside to cool, when the carbolic acid crystallises, while the cresylic acid holding some carbolic acid in solution remains liquid. The liquid matter is then drained off through an opening near the bottom of the vessel, and is subjected to a second distillation for the obtaining of the carbolic acid it contains. When all the liquid has been drained off from the crystals, or removed by the aid of a centrifugal machine, the carbolic acid obtained is again distilled, and the cresylic acid, after crystallisation of the carbolic acid in the receiving vessels, is drained off by inverting the latter over a trough. By the first distillation and crystallisation, as conducted at Lowe's Works, a carbolic acid crystallising at 85° Fahr. is obtained. The second distillation and crystallisation gives an acid crystallising at 95° Fahr. The acids, of the fusing points mentioned above, are next melted in a steam jacketed vessel and mixed with water, after which they are made to crystallise by the application of artificial cold, the result being a crystal composed almost entirely of carbolic acid and water; the liquid hydrate of cresylic acid is separated mechanically in the usual manner, and the solid crystalline hydrate of carbolic acid is submitted to fractional distillation, by which process the fusing point of the dry acid is raised to 108° Fahr. All these are "commercial" acids, and for medical purposes still require refining, in order to remove from them the last traces of neutral hydro-carbons, of the offensive sulphuretted compounds, tar bases, &c. At Calvert & Co.'s Works the commercial acids are refined by suitable acid treatment for the removal of the bases and neutral hydro-carbons, and by treatment with acetate of lead for the removal of sulphuretted hydrogen. After this the acid is redistilled in glass retorts heated by a sand bath, each retort taking a charge of about 40 lbs., of which 4-5ths are distilled off. The residue in the retorts is a blackish treacly substance which crystallises imperfectly, and which is dealt with elsewhere, for the recovery of such carbolic acid as it contains. The liquid cresylic acid which results from earlier operations is refined in a similar manner by distillation with acetate of lead, but an iron still is used for this process, and the distillation is carried to the production of a coke. Offensive uncondensable gases are given off towards the end of this process.

Whether the still and condensers be or be not situated in the open air, the collection of the products of the distillation is always conducted within a building of some sort, as also are all the operations of draining, &c.

Nuisance.

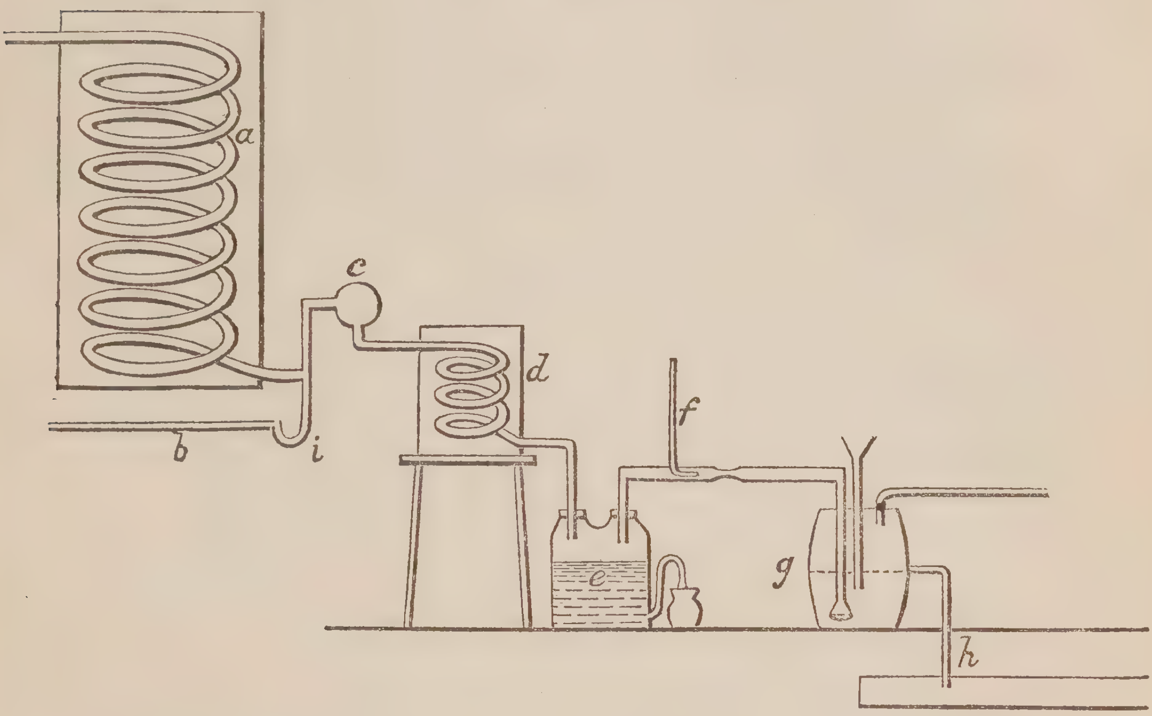
Carbolic acid works are apt to be a source of nuisance to immediate neighbours, the emanations proceeding from them being said to be sometimes offensively perceptible for a distance of at least 100 yards. The chief sources of the nuisance are the escape of offensive gases towards the end of those distillations in which a coke is produced, the process of removing the coke from the still, and the odour of impure carbolic acid which is wafted by the wind from the works as it blows through them.

Prevention of nuisance.

The best arrangement I have seen to prevent nuisance from the escape of the offensive uncondensable gases was at Mr. Lowe's Works at Reddish. Fig. 19 is a rough plan of this arrangement. The pipe from the worm condenser *a*, at a distance of a few inches from

it, divides into two branches, one of which *b* descends, carrying off the condensed liquid, which by means of a bend *i* in the pipe traps it, while the other branch ascends, and conducts any uncondensed gases to a 6-inch main pipe *c*, which runs along the front of the whole range of stills. From this main a pipe conveys the gases to

Fig. 19.



a small worm condenser *d*, and from this to a stoneware bottle *e*, which receives all liquid matters that this small condenser may separate. A pipe proceeding from this bottle is supplied with a steam jet *f*, which draws upon the gas main and drives the gases onwards through water or milk of lime, contained in a cask *g*, whereby sulphuretted hydrogen is arrested, and from this washer a pipe conveys any gases not arrested into the ashpit of a fire. Should the gases chance to ignite, the ignition would not proceed further back than the cask.

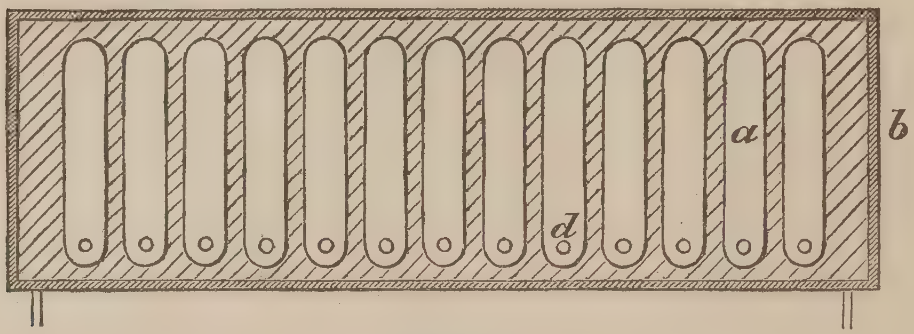
With respect to nuisance arising during the removal of the coke, Mr. Lowe tells me that it only occurs when the distillation has not been carried far enough, and when consequently the coke is not dry. The remedy, therefore, appears to be obvious. In addition, the still might, if necessary, be cleared of offensive gases, by the use of the steam jet in the apparatus just described, Fig. 19.

The general odour of impure carbolic acid perceived about such works as these may be lessened considerably by receiving the condensed liquids not into open but into covered vessels. That it is quite practicable to do this, at any rate in large works, is proved by the fact that it is done at Mr. Lowe's Works. The rough plans, Fig. 20, indicate the sort of arrangement adopted. It consists of a series of thirteen deep narrow iron pans *a* set side by side with intervals of a few inches between them within a wooden case *b* filled with brine, which can thus circulate around and between them. All the upper part of this case is closely covered, so that looking down from above the only parts seen to be open at any time are the tops of the receiving pans. For these open tops wooden covers are provided, which are kept on during all the time the stills are running. The products from the condensers are brought by a pipe *c* having small branch pipes with taps opposite the several receiving pans, which pipes discharge into the pans below their covers. Should

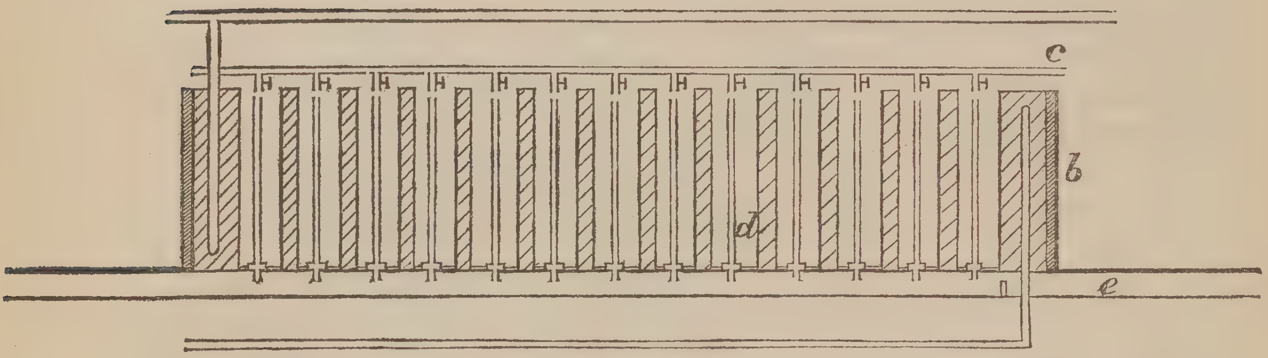
any pan, in consequence of want of watchfulness, become too full, the surplus can run off from the upper part by a waste pipe *d*, screwed into

Fig. 20.

Plan.



Section.



the bottom of the pan, into a drain or channel *e* beneath leading to the liquid acid tank. The brine with which the case is filled circulates through it from a freezing machine. In this way crystallisation of the acid is obtained speedily and more completely than in the ordinary way, nuisance being also avoided. When the crystallisation is complete the pans are uncovered and the pipes are removed, and then the liquid portion runs off into the drain or channel provided to convey it to its appropriate tank. Covered receivers, having a provision for overflow into other covered receivers, are also in use at Graicher's Works at Cefn.

THE MANUFACTURE OF PICRIC ACID.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 20, 1876 -	Storey - -	Lancaster -	Manufacture of carbolic acid.
Mar. 27, 1878 -	Charles Lowe & Co.	Reddish, near Manchester.	Ditto.
Feb. 24, 1879 -	John Casthelaz -	Blackley, Manchester.	Manufacture of aniline.
„ 27, „ -	Longshaw and Sons.	Sankey Bridges, Warrington.	Manufacture of carbolic acid and nitric acid.
May 13, „ -	Corbett & Co. -	Cefn, North Wales -	Manufacture of carbolic acid and nitric acid.
„ „ „ -	Graicher -	Ditto - -	Ditto.

Process.

Picric acid is prepared by the action, with the aid of heat, of strong nitric acid upon carbolic acid crystallising between 85° and 108° Fahr.

This operation is at some works conducted in glass retorts, but most commonly now in stoneware pots or in iron pots enamelled inside. The nitric acid used is first dehydrated by the addition of oil of vitriol. The form and exact size of the pots vary in the different works I have visited, but they are always covered, and from the cover a pipe conveys away nitrous fumes which are given off. The heat is applied either by a fire or a sand bath, or a bath of chloride of calcium, or steam heat is used. On the completion of the conversion of the carbolic into picric acid the contents of the pots are siphoned off into a vessel kept cool by cold water, and here the acid crystallises. The remaining processes consist of straining the crystals, redissolving and recrystallising, and finally in drying the finished acid upon shelves in a heated chamber.

Nuisance.

The acid fumes from this process have been a cause of complaint on the part of neighbours, where insufficient means or no means at all have been adopted to arrest them. In one case that I was informed of, complaints were made of their irritating quality, and especially of their producing spasmodic cough and oppression of breathing.

Prevention of nuisance.

The best way of dealing with the vapours is to condense them. This may be done by collecting all the fumes from a row of pans or retorts in a main pipe, and conducting them from it through a sufficiently long series of Woulffe bottles containing water; or, as at Mr. Casthelaz's Works, by connecting each pot with a Woulffe bottle, and all the bottles in a row with one another, carrying the fumes from the last of the series through three or four more bottles on their way to the chimney shaft. At Storey's Works the main pipe running from all the pots conveys the fumes to a stoneware pipe tower about 10 feet high filled with coke through which first water and then the first formed weak acid is made to trickle repeatedly, until the acid has acquired sufficient strength for use. It is well to conduct the final vapours through a fire, by which any nitrous compounds remaining uncondensed would be decomposed. It is not a good plan to trust a fire alone, since, unless it be carefully kept up, fumes may pass undecomposed through it.

THE MANUFACTURE OF ANILINE AND ANILINE COLOURS.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 28, 1878 -	Atlas Works (Brooke, Simpson and Spiller).	Hackney Wick.	—
" " " -	Phœnix Works (W. C. Barnes).	Ditto - -	Manufacture of nitric acid. Concentration of sulphuric acid.
Mar. 30, " -	Clayton Aniline Company (Limited).	Clayton, Manchester.	Manufacture of nitric acid.
April 4, " -	Roberts, Dale & Co.	Warrington -	Manufacture of nitric acid and acetic acid.
May 20, " -	Dan Dawson Brothers.	Milnes Bridge Huddersfield.	—
Feb. 21, 1879 -	Manchester Aniline Company.	Clifton Junction, Manchester.	Manufacture of nitric acid.
" 24, " -	John Casthelaz -	Blackley, Manchester.	Manufacture of nitric acid and picric acid.
" 26, " -	L. J. Levinstein and Sons.	Ditto - -	Manufacture of nitric acid.

Process.

The crude material out of which the aniline oils are manufactured is tar light oil or "naphtha," obtained by the distillation of tar. The processes or steps of the process which it will be necessary for me to sketch are: 1. The fractionating of the naphtha. 2. The preparation of nitro-benzole and bi-nitro-benzole. 3. The preparation of aniline oil. 4. The manufacture of arsenic acid. 5. The preparation of magenta (*Syn.* Rosaniline, Fuchsine, &c.). The sketch need only be a light one. The above processes are not invariably all carried out at aniline works. At some the light oil is purchased ready fractionated, at others arsenic acid is not made; at some the processes terminate with the preparation of the aniline oils, while at others they commence with these oils which have been purchased from aniline makers.

1. Fractionating naphtha.

1. *Fractionating the light Oil or Naphtha.*—The naphtha is first purified by distillation in a still, heated by steam at about 50 lbs. pressure introduced into an outer casing, no fire being used. Towards the end of the distillation free steam is thrown in by means of a perforated coil at the bottom of the still. Naphtha and water are condensed by a worm condenser and received into a covered vessel, the residue in the still being a tarry substance which is sent away to make (as is believed) lubricating grease. The water is separated from the naphtha floating above it by siphoning, and the naphtha is then introduced into an iron cylinder provided with a mechanical agitator, where it is heated with oil of vitriol. The naphtha is subsequently washed with water, then heated in the same vessel with some caustic soda and washed again, and is thus obtained in a colourless condition. Tarry matters separated, are, with the acid liquors, &c., usually discharged into the drains. The purified naphtha is then subjected to fractional distillation by means of steam heat. The object is to obtain naphtha capable of furnishing at 212° definite per-centages of benzole, these per-centages being 90 or 80, 50 and 30, according to demand or the requirements of the trade. These several kinds of naphtha are given off during certain definite stages of the distillation, and they are collected separately. There are various ingenious forms of apparatus designed to effect this separation with accuracy, but it is not necessary to describe them here. The final product distilled off is known as "solvent naphtha," used in the manufacture of india-rubber. The residue in the still is a mixture of solvent naphtha and naphthaline, and is usually run off to an underground tank, whence it is sold for making lamp-black.

2. Preparation of nitro-benzole.

2. *The preparation of Nitro-benzole.*—The fractionated naphtha, now known as "benzole," of this or that per-centage, is made into *nitro-benzole* by the following process: A cylindrical iron vessel set vertically is used. It is provided with a mechanical agitator, and either with a jacket containing cold water, or with a perforated pipe round the cylinder near the top, from which cold water flows over the outside into a trough below, from which it runs away; some means of cooling being necessary to control excessive action within the vessel. On a shelf, a little above this vessel, is a stoneware jar containing a definite quantity of nitric acid, to which oil of vitriol has been added in order to strengthen it. The benzole having been introduced by an opening at the top, and the opening securely closed, the nitric acid is run in slowly from the jar in a continuous stream by means of a siphoned delivery tube, and the agitator or stirrer is set to work. Heat is evolved and is moderated by the cooling arrangement outside. If the action becomes excessive or if too much nitric acid should be flowing in at any time, nitrous fumes are apt to be evolved, and there is a provision of a stoneware pipe from the top of the cylinder to permit of their escape. When all the nitric

acid has been used up, which is usually in the course of 10 or 12 hours, the benzole is known to be converted; the agitator is then stopped and the whole is left to become cool. The charge being put in in the morning, the operation is usually over in the evening, and the night is thus devoted to cooling. The contents of the cylinder (impure sulphuric acid at the bottom, and nitro-benzole above,) are then either siphoned off or run off from a tap near the bottom, first the acid and then the nitro-benzole. At some works these are run from the tap by means of a funnel-pipe directly into carboys, but usually there is a leaden gutter passing along below the taps of a series of similar stills into which they are run, and by which the acid first and the nitro-benzole next are conducted into their proper separate receptacles. The nitro-benzole, which has now the well-known strong odour of oil of bitter almonds, is next washed with water to cleanse it from acid; this is sometimes done in the cylinder in which the nitro-benzole has been made before drawing it off, otherwise it is done in a properly covered vessel provided with a mechanical agitator. The washing water, which is acid, is run off into the drains. At some works the nitro-benzole is distilled in a steam-jacketed vessel to purify it further; in this case if 211 gallons are distilled 123 are distilled off, the residue in the still being sent away for the scenting of brown soap. What is known in the trade as "essence of myrbane," and is used for scenting soap, is obtained from nitro-benzole by putting it into a still and blowing steam through it by means of a perforated worm tube reaching to the bottom. The steam and essence of myrbane are condensed by a worm condenser and collected together in the same vessel, where they separate in accordance with their relative gravities. In the preparation of *bi-nitro-benzole* a cylinder similar to that used for nitro-benzole making is used, but it has a steam jacket into which superheated steam is blown. The nitro-benzole having been introduced into this vessel, a definite quantity of the strongest nitric acid to which oil of vitriol has been added, is gradually run in by a siphon delivering pipe; nitric acid and nitrous acid fumes come off and require to be conducted away by a pipe and condensed. When the conversion is complete, the contents of the cylinder are either siphoned off or run off by a tap. The sulphuric acid first drawn off is sometimes discharged into the drains, but in other works is collected, and after standing until the bi-nitro-benzole it contains has solidified and been removed, is rectified for use again. (*See also* p. 313.) The bi-nitro-benzole is run off by means of a siphon or by a pipe luted on to the tap of the cylinder into a covered tank, where water is added to it, and the whole is heated by steam blown in. The bi-nitro-benzole thus washed is then siphoned off into shallow stone troughs to solidify.

3. Preparation of aniline oil.

3. *The preparation of Aniline Oil.*—The materials used are nitro-benzole, iron filings (sometimes previously ground to a meal), and generally hydrochloric acid. At some works acetic acid is used. The apparatus employed consists of a vertical iron cylindrical still (although there may be some modification of this form) provided with a mechanical stirrer, the shaft of which is hollow for the conveyance of steam to the hollow perforated arms through which the steam is, when required, blown into the still. The ordinary practice is to introduce into the still the nitro-benzole mixed with the requisite quantity of acid, and through a funnel at the top to introduce from time to time definite quantities of iron filings until the total quantity requisite for the conversion has been supplied. In some works, however, the acid and iron filings are introduced together and the nitro-benzole gradually run in. No heat is applied, sufficient heat to distil off the aniline oil arising from the chemical action that ensues. The agitator is worked during the whole

process of conversion, and the distillate is condensed by a worm condenser. In some works the products as they become condensed are, by means of a cohobating arrangement, returned in a constant steam to the still, but at other works they are collected and returned to the still all together. When the conversion is completed, the oil is distilled off by means of steam blown in through the shaft of the agitator; the result of condensation is aniline oil and water, which are received in an appropriate tank where they separate, the aniline oil falling to the bottom. After a short time the one can be drawn off from the other. The aniline oil is purified by distillation. The water, still containing some aniline in solution, is run off into a tank. Of course this small quantity of aniline is valuable, and hence in some works the condensed water containing it is used the next day instead of fresh water to supply steam for the aniline stills.

4. Manufacture of arsenic acid.

4. *The manufacture of Arsenic Acid.*—It is only at aniline works that I have seen arsenic acid made, so that this appears to be the proper place to mention the manufacture. In such works there has been but one mode of making it, namely, by the action of nitric acid upon arsenious acid. In this process, part of the oxygen of the nitric acid goes to supply the requisite oxygen for converting the arsenious into arsenic acid, while the rest goes off as some lower oxide of nitrogen which forms red nitrous fumes on mixing with air. The vessel used for the decomposition is, at the Phœnix Works, an iron cylinder lined with fire-bricks cemented together with an appropriate cement. It is steam jacketed, ordinary steam being used for heating. The materials are introduced by a hole at the top, capable of being covered. The fumes given off are carefully condensed; the exact method used for their condensation differs in different works in the manner to be hereafter described.

5. Preparation of magenta.

5. *The preparation of Magenta.*—A charge of aniline oil is introduced into a cylindrical vessel in which is a mechanical agitator, the arms of which are mostly so arranged as to be capable of scraping in succession all the lower parts of the interior of the vessel. Into this vessel thus charged a strong solution of arsenic acid is run in, and a gentle heat is applied by a fire beneath. During the action that ensues some aniline of great purity distils off and is condensed by a worm condenser. The process is known to be complete when a definite quantity of aniline has been collected. A man-hole at the lower part of the still is then opened, and the contents of the vessel, then known as "red-melt," are run off as a doughy mass and conveyed away for further manipulation. The red-melt has now to be deprived of the arsenic acid it contains. I shall describe this process and the succesive steps of the preparation as I saw them conducted at the Atlas Works. The melt is carried to an elevated platform in a large chamber ventilated by lantern louvres at the roof, and is there put into a circular tank containing water which is heated, while at the same time the contents of the vessel are made to circulate by the injection of free steam into it at a proper angle. This tank is in great part covered, but a part of the top is uncovered to allow of the operation being duly watched. The solution of the red-melt is now run off into another tank where it is treated while hot with milk of lime, which throws down the arsenic acid as an arseniate of lime mixed with more or less of the colouring matter. From this the solution is run off hot into a calico-filter stretched over another tank, from which it again runs away to large iron coolers or crystallising tanks on the ground-floor. The arseniate of lime is, after being pressed, sent away as refuse. As the solution cools in the iron tanks it deposits the magenta in a crystalline form upon the sides of the

vessels, and then the mother liquor is run off into underground tanks, from which it is pumped up again into the solution tanks on the platform above, to be used instead of water. I was informed that the cooling in the iron tanks must necessarily be conducted slowly, so as to prevent the deposition of the magenta in a powdery form, which would be very inconvenient. After repeated charges of the tanks, sufficient magenta becomes crystallised to permit of its removal for further manipulation. Coolers situated out of doors are sometimes used in the summer time. In some other works the red-melt is, with the aid of heat, dissolved in water acidified with hydrochloric acid, and the hydrochlorate of rosaniline is then thrown down by the addition of common salt, the hydrochlorate not being soluble in brine. The subsequent processes to which the magenta is subjected need not be described. Neither is it necessary for the purposes of this Report to describe the preparation of the other various colouring matters made from magenta and the aniline oils. It may suffice to say that in making many of them heat has to be applied, and vapours are given off which are all readily capable, when offensive, of being effectually dealt with so as not to create a nuisance.

It is necessary to say that all the processes which I have been describing are conducted within a building or beneath a shed open on one side to the air. The latter is preferred for the manufacture of nitrobenzole and bi-nitro-benzole on account of the danger which sometimes attends it.

Nuisances and sources of nuisance.

Aniline making is a trade which has on several occasions been complained of as a source of nuisance, the nuisance consisting in the diffusion outside the works of nitrous fumes or of an odour of oil of bitter almonds. The former is decidedly disagreeable and irritating to the organs of respiration, and, where complaints have arisen, is the nuisance which has mostly, I believe, been meant. The latter, the odour of myrbane, is rather an agreeable odour, that is to say, its character is agreeable to most people; but even a pleasant odour may become a source of offence when it is persistent, or nearly so. I am, however, not aware of any imputation against it of having in any way proved injurious to health.

The sources from which nitrous fumes may emanate are the preparation of nitro-benzole and bi-nitro-benzole and the manufacture of arsenic acid (or of nitric acid when this is made on the premises). Of course to allow these vapours to escape at all is a loss to the manufacturer, but, for all that, more or less of them is not rarely allowed to escape, either because no provision has been made to arrest the fumes, or because the means provided for this purpose have been neglected or allowed to fall into disuse, or from bad working and leakages in the plant.

The interior of aniline works is mostly pervaded with the myrbane odour, but it ought not to be so excessive as to give annoyance outside the works. It is perceptible within the works whenever any of the distillations are going on, and is due to slight escapes of uncondensed vapours, or to escape of vapours during the discharge of the melt. In the room in which the melt is dissolved and subsequently dealt with, watery vapour having the characteristic odour of aniline is given off in great abundance, and passing out from the building the steam may, in some conditions of the weather especially, hang disagreeably about the neighbourhood, and give rise to offence. In addition to this, acid matters discharged into drains may, if they reach public sewers, cause annoyance by their action on the contents of the sewers, giving rise to the evolution of offensive gases.

APP. No. 6.

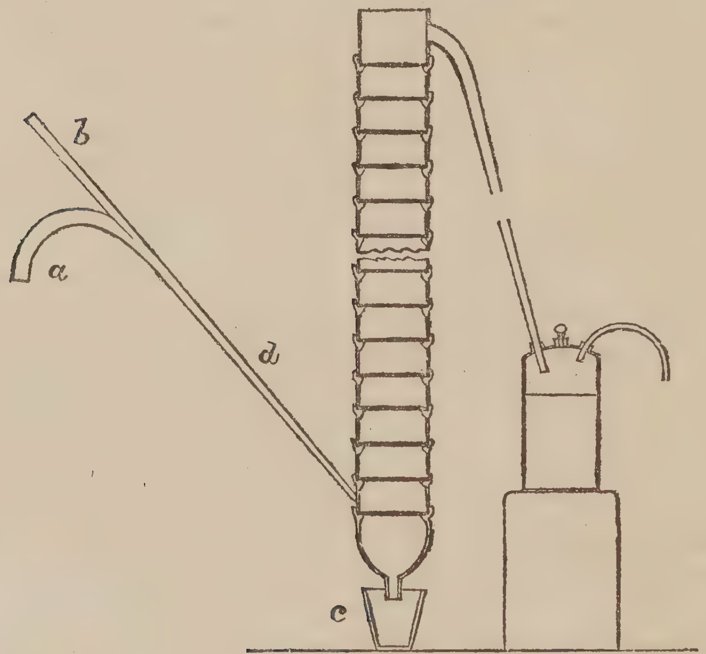
On Effluvium Nuisances, by Dr. Ballard.

When sulphuric acid is concentrated by boiling down, sulphurous acid may be evolved by the action of the acid upon the organic matter it is mixed with ; and this may create nuisance.

Prevention of nuisance.

Escape of nitrous fume from the nitro-benzole apparatus is an indication that the action within the cylinder is too fierce. It is more apt to occur in the summer when the water used for cooling is not cold enough for the purpose; it may also occur when the nitric acid is allowed to run in too fast. Whenever it occurs then, the proper thing to do is to turn off the nitric acid for a time, and to allow the cylinder to cool a little. But to obviate the accidental nuisance which may arise from these causes or from negligence of workmen, the tube conveying away the acid fume ought to be connected with a condenser. For the most part the condenser used consists of a series of Woulffe's bottles. It is important that there should be a sufficient number of them, and the last should communicate with the chimney shaft. The stopper of the first bottle being taken out any occurrence of escape of fume will be observed, and the stopper can then be replaced until the escape is obviated by reducing the violence of the decomposition in the cylinder. In one work that I visited the escape pipe communicated with a spiral pipe having a free opening above and passing up through a bottle intended to contain water. It was supposed that the fume would have been condensed by this means as it ascended the spiral, and that the condensed acid would have run back into the cylinder. But it was obvious that this had not been the result, since the galvanised iron of the side of the building had been corroded opposite the end of the escape pipe, leaving a large hole. It is necessary also to make due and sufficient provision for the condensation of the nitric acid fumes proceeding from bi-nitro-benzole making. At the Phœnix Works they are made to pass first through a tower constructed of stoneware pipes (as shown in the rough diagram Fig. 21), each section of which has within it two perforated stoneware

FIG. 21.



diaphragms; on passing away from the top of the tower the fumes are carried through a series of 20 Woulffe's bottles, the last of which is connected with a flue leading to a chimney shaft 95 feet high which exercises some traction influence. In the pipe *a* proceeding from the

still to the tower there is a provision by means of an open offshoot *b* for the admission of air to mix with the fume given off. Whatever acid becomes condensed in the tower is collected in a pan *c* below.

For collecting the acid fumes from arsenic acid making, a similar arrangement is adopted. Mr. Levinstein condenses these fumes very effectually, as he informs me, by means of a pair of stoneware pipe towers of 30 inches diameter and 40 feet high, which are packed with coke and supplied with water from the top. The fumes are conducted up the first, then by a pipe to the bottom of the second tower, from the top of which such fume as fails to be condensed passes by a pipe to a flue leading to the chimney shaft 120 feet high. The loss of acid up the chimney is said to be only 2 per cent. of that used. At another establishment that I visited, the nitrous fume from the nitro-benzole and arsenic acid processes was, by an ingenious arrangement, churned with a solution of caustic soda, by which it was absorbed with the formation of nitrite of soda which is in common use for the manufacture of Bismarck brown. Where aniline vapour is given off in running out the "melt," the use of a hood has been recommended for the protection of the workmen; such a hood, being made to communicate with the chimney shaft, would at the same time obviate all chance of external nuisance from this source. A similar provision is applicable to several of the processes of colour making.

I have not in any works that I have visited seen any attempt made to dispose inoffensively of the more diffused vapours emitted into the works, such, for instance, as those which issue during the processes of solution, filtration, and cooling of the melt. Should these vapours create nuisance, it might no doubt be obviated by ventilating the entire chamber into the chimney shaft of the works, either by means of a fan or otherwise. At least the pan in which the melt is dissolved might be provided with a cover and pipe for conveying off the steam to the chimney shaft, a condenser being interposed if considered desirable. Condensed products of distillation should in close neighbourhoods be received into covered vessels.

Acid refuse should be received into a proper tank on the premises, there to be cooled and neutralised with lime before the liquids are run off into the public sewers. (*See* p. 248.) In one establishment where the concentration of the acid drawn off from the nitro-benzole and bi-nitro-benzole stills created a nuisance, it was practically obviated by passing the vapours given off up a leaden tower filled with coke, through which water was made to flow freely.

THE DISTILLATION OF OIL-SHALE.—PREPARATION OF PARAFFIN AND MINERAL OILS.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
June 23, 1876	Bremner - -	Pendleton, Manchester.	—
March 6, 1877	Price's Candle Company (Limited).	Battersea - -	Distillation of palm oil, tallow melting, and manufacture of soap and candles.
" 9, "	Ogilvy - -	Lambeth.	—
Oct. 13, "	Walker - -	Tunstall.	—
" 20, "	Chatterley Oil Works.	Ditto.	—

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Oct. 24, 1877	Jones - -	Milton, Burslem -	Tar distilling. Manufacture of sulphate of ammonia.
June 5, 1878	Loan-head Oil Works.	Straiton, near Edinburgh.	Manufacture of sulphate of ammonia, and lime burning.
„ 13, „	Young's Paraffin and Mineral Oil Company.	Addiewell, West-Calder.	Manufacture of sulphate of ammonia.
„ „ „	Oakbank Oil Works	Midcalder	Ditto.
„ 14, „	Ross - -	Falkirk - -	Tar distilling. Manufacture of sulphate of ammonia.
„ 18, „	Robin and Houston	Glasgow - -	Distillation of palm oil.
May 19, 1879	Dee Oil Company	Saltney, near Chester.	—
„ „ „	Flintshire Oil and Cannel Company	Ditto.	—

Sources of paraffin.

There are, in so far as trade processes in this country are concerned, three ordinary sources of commercial paraffin with which this Report has to do, viz., native "ozokerit," or earth-wax, mostly imported from Galicia; a natural mineral oil, or "petroleum," of which the most important source at present is the United States, and which is occasionally found in small quantities in this country; and lastly, the distillation of bituminous shales found in the coal measures in various districts of England and Scotland.

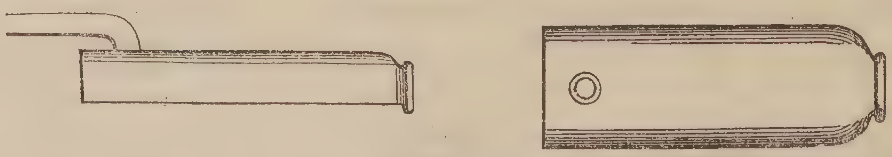
Distillation oil-shale,

1. *Distillation of Oil-shale.*—This shale being bulky is always distilled near the pits from which it is obtained. The crude products of distillation are also mostly dealt with for the preparation of the mineral oils and paraffin at the same places, but in some cases are sent away elsewhere for this purpose. The most complete as well as the most extensive works of the kind are those of the Paraffin Light and Mineral Oil Company at Addiewell, since here all the operations are performed up to the refining of the oils and the paraffin, and the manufacture of candles from the latter. At other works the operations are conducted on scales which vary considerably. Some of the works I visited are comparatively very small works. The operation of distilling shale may be briefly described as follows: 1. The shale is broken up into pieces of a convenient size for charging the retorts, either by hand or by the use of a crushing machine. 2. The distillation is effected in retorts either entirely exposed to the air, or merely covered with a light roofing or shed. The form of the retort and the mode of conducting the distillation vary in different places. At the Chatterley

Staffordshire;

Works in North Staffordshire, where the shale used is that which lies in a seam of about 18 inches thick immediately above the rich red-mine ironstone, the retorts of cast-iron used are those known as "horizontal"

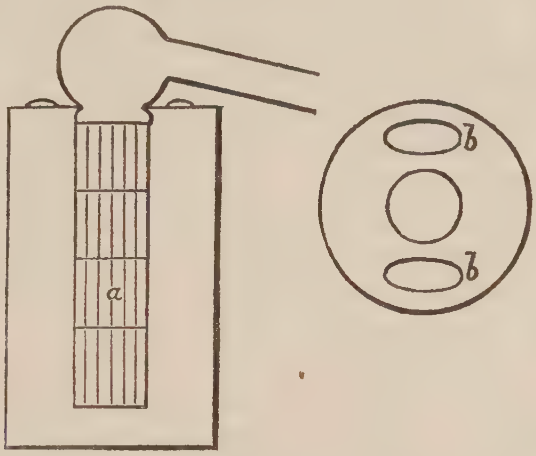
Fig. 22.



retorts. The shape is not very material, but Fig. 22 shows the shape in use in these works: the retorts are flat-bottomed, arched at the top, 12 feet

long, and 4 feet 6 inches wide, and 2 feet high. Such retorts are set in brickwork, in a row or bank, and are heated by a fire below and by flues, the heat used being a dull heat short of ignition. They are charged at the open extremity, a lid like that of a gas retort being then adjusted. In 24 hours the distillation is completed, and then the lid is removed and the charge is drawn into waggons which convey the spent shale to a heap. This kind of shale, after having been drawn, ignites, and when thrown on the tip burns to a cinder which contains much iron and is used then for smelting purposes. At Messrs. Jones' works at Milton, where "cannel" and "peel" from the same coalfield are distilled, vertical retorts of the shape indicated in Fig. 23 are used. Each retort is capable of distilling two tons of shale, and the distillation lasts 48 hours.

FIG. 23.



The middle of the retort is occupied by an iron cage *a*, the object of which is to keep a clear passage in the centre for the rise of vapours. The retorts are charged by two oval openings on the top *b*, and discharged by a man-hole near the bottom. They are heated by a fire beneath. The drawn charge, not being so rich in iron, is used to fire the next charge, or cast on a heap to burn away. At Falkirk, oval horizontal retorts about 9 feet long, $2\frac{1}{2}$ feet wide, and $1\frac{1}{4}$ feet deep are used to distil shale from the "musselband" seam. Vertical retorts, but of a construction different from what I have described, are apparently the favourite retorts in Scotland. The following are three forms that I have seen in use, all three being adapted to the system of continuous charging; the difference between them having reference to the arrangements at the lower extremity of the retorts. At Young's works at Addiewell the retorts are vertically-set iron tubes or flattened cylinders about 12 feet long, their greatest width being 21 inches, and their least about 14 inches. They are set in banks, the charging openings, which are funnel-shaped, being on the level of the top of the bank, and being provided each with a domed cover which is luted on by a little fine sand. The lower end of the retort is open and dips into an iron trough containing water, which lutes or seals it, and from which the spent shale is drawn quenched by the water in the trough. A jet of steam is thrown into each cylinder near the bottom. As the shale falls in a cylinder, more is charged in at the top. One fire heats three such retorts. The quenched spent shale is said by the manager, Mr. Calderwood, to contain about 16 per cent. of combustible matters. At the Oakbank works at Midcalder, where Mr. George Beilby is manager, the same shaped retort is used as at Addiewell; the bottom, however, does not dip into water, but is closed by an iron plate which, while the retort is working off, is wedged closely up. When the retort

in Scotland.

has to be discharged the wedge is removed, the plate falls, and an arrangement comes into play by which the spent shale is made to fall into the fire which heats the retorts. In addition to this, uncondensable gases which are part of the product of the distillation are used in heating the retorts. At the Straiton Oil Works the bottom of the retorts is constantly open, and the spent shale as it falls out is ignited, and the combustible constituents are all burned off by the assistance of waste uncondensable gases conducted to the spot by branches from a main pipe. Nothing but ash is removed from the fires.

Condensation of the oil.

The principle of condensation is the same everywhere, but the details vary in perfection or completeness in different works. The cooling action of the air as the products pass through iron pipes is the principal agent in the condensation. These pipes are sometimes laid horizontally, as at Chatterley and Falkirk, and then the condensed products fall into the lowermost segment of the pipe, and are run off from thence; or they are placed vertically like the continuous condenser of a gaswork, and then the condensed matters fall into a receiver or appropriate covered channel beneath. The most perfect air condensation I have seen is at Addiewell, where there are 16 rows of very tall tubular condensers, each with a collecting main below. By this means not only is an excellent condensation obtained, but a first separation of the products is effected. A heavier oil collects in the first six collecting mains, and a lighter oil in the last ten, and then the two kinds of oil are conducted away separately for separate subsequent treatment. The lighter oil collected by this means constitutes only six per cent. of the whole of the condensed matter. This result, however, seems to show that, in works where the air condensation is less perfectly provided for, a good deal of valuable matter is thrown away. In another part of the works, where the continuous condensers are smaller, the condensation is assisted by running water down the outside of the tubes. In addition to the oil condensed, each ton of shale furnishes 115 gallons of an ammoniacal watery liquor. But it has been found that the gas that is left still contains some condensable "naphtha," or light oil, to obtain which the gas is passed through a tower or scrubber filled with coke, down which a spray of heavy mineral oil is run, which dissolves out the light oil. In order to separate the light oil from the solution in the heavy oil, the former is distilled out in a sort of Coffey still,—in this case a tower provided with wire gauze partitions,—down which the oil, previously heated with waste steam, is run, while steam is thrown in below. In this way a spirit, sold as "gazoline," is obtained, and condensed in a covered condenser with the steam that carries it off. The final gas thus thoroughly cleared of condensable matter is purified with lime from carbonic acid and sulphuretted hydrogen in the ordinary way, and is used for illuminating purposes. A somewhat similar method of separating the final spirit from the gas is adopted at Straiton and at Oakbank, at both of which places the waste scrubbed gas is used to assist in heating the retorts. At most other works the uncondensed gas, containing, as must be believed, some yet condensable matter, is either burned as it issues into the air from escape pipes or else under boilers.

The further processes at oil works consist in the rectification of the oil, the preparation of solid paraffin, and the manufacture of sulphate of ammonia from the ammoniacal liquor.

Rectification of oil.

The rectification of the crude oil thus obtained is effected by distillation in an iron still, by means of a fire beneath and the injection of free steam into the still. Steam is similarly used in all subsequent distillations and rectifications. The object of the distillations is to

fractionate the oil into oils of various densities or boiling points. At Addiewell the oil is not fractionated as it runs from the first still, but at some other works it is, the oil given off at three separate stages of the distillation being collected separately; the first that comes off being light or "burning oil," the next "intermediate" or "torch oil," and the third and last, heavy "pressing" or paraffin oil, from which the "paraffin scale" is extracted. The residue in any case is a light spongy coke, which is valuable as a fuel. At Addiewell the fractionating is performed at a later stage. But different works follow different practices in this respect and in respect of the precise plans they adopt to effect the production of the oils they desire to manufacture. These differences of practice depend mainly upon the precise sort of oil the manufacturers have to work upon, and the quantity of solid paraffin that is to be extracted from it. Assuming that at the first distillation three kinds of oil are separated, viz., "burning oil," "intermediate oil," and "pressing" oil, the mode in which these three are separately dealt with must be described. *a.* The light oil is first agitated in a tank with sulphuric acid by means of an appropriate stirrer, and being then left at rest for about two hours, it deposits a tarry substance known as "acid-tar." It is then run off into another tank, where it is similarly agitated with a solution of caustic soda, and here again it deposits a tarry matter known as "soda-tar." It is then again distilled, again treated with acid and soda, then redistilled, and a third time treated with acid and soda, with a view to remove all colour before being sent out. *b.* "Intermediate" or "torch oil" is sold as it is produced. *c.* The "pressing" or paraffin oil is either again distilled or is at once set to cool in tanks, where it crystallises. The solid matter thus obtained is put into bags, from which an oil partly runs out and is partly pressed out by a press, crude scale paraffin remaining in the bags. But the oil that is thus separated still contains paraffin, to obtain which it is forced through a freezing machine, which separates more solid paraffin, into bags from which a lubricating oil runs off. At Addiewell the paraffin is separated from the oil by causing a drum containing cold brine or glycerine and water to revolve in a tank of the oil. The paraffin crystallises on the drum as it revolves, and is scraped off. The paraffin obtained by any of these processes is known as "scale" paraffin, in which form it is usually sent away from the oil works to be purified elsewhere.

Scale paraffin.

2. At some works in this country rock oil or petroleum, in a condition known as "American residuum," is dealt with. It is the petroleum in the condition in which it is left after the separation of a light oil from it before exportation. This material arrives in casks, which are emptied by the injection of steam, in the same way as casks of tallow, when the weather is so cold as to require this aid. The oil is distilled like crude shale oil, and the process to which the distillate is subjected is similar to that to which the crude shale oil is subjected for the production of oil of varying densities and of scale paraffin. At the Dee Oil Works, the oil, while being treated with acid, is agitated by driving a blast of cold air through it.

2. Distillation of rock oil.

This appears the proper place to state how the "acid-tar" and "soda-tar" obtained in the purification of the crude oil are dealt with. At some works which I have visited it has been the practice to bury them in the earth; but this proceeding has after a time been productive of inconvenience, in consequence of the saturation of the earth around the place with oil. To avoid this it is in some works the practice to burn the tars either by throwing them upon the coke used to heat the stills or in some other way. At Addiewell the sulphuric acid which the acid-tar contains is first separated by passing steam through the tar, the

Mode of dealing with the tars.

acid thus obtained being used subsequently for making sulphate of ammonia, and then the tar is burned in the furnaces. A bank of red hot fuel is kept up near the mouth end of the furnace, and the tar flowing by a pipe from a supply tank above, drops into a hollow space behind the fuel, and is there consumed. At the same works the soda-tar has the soda first dissolved out of it by mixing it with water in a tumbler or revolving cylinder placed horizontally, through which carbonic acid from burning coke is continuously passed. The tar, after having been thus treated, is similarly burned in the furnaces.

3. Purification of paraffin.

3. Ozokerit and "scale paraffin" are dealt with much in the same way for the purpose of purification. The following is the method adopted at Price's Candle Company's works at Battersea. The material is melted out of the casks it arrives in, by means of free steam, into a tank, from which it is pumped into large iron pans, where it is boiled by means of the free steam. Here it deposits various impurities. The paraffin is drawn off into shallow iron pans to solidify into cakes. These cakes, supported upon coarse matting, are then subjected in hot iron closets to sufficient heat to sweat out oily matter contained; and the paraffin, thus rendered whiter and harder, is subjected to processes of heating and steaming, and subsequently to treatment first with acid and then with alkali, some tarry matter being separated in both cases. Subsequently the paraffin is bleached with ivory black. At Ogilvy's works at Lambeth the paraffin which reaches the works in the moulded form is purified by what is known as the "Fordred and Storry process." There is a wooden tank containing a solution of carbonate of soda, and in it, by a mechanical arrangement of cylindrical wooden revolving frames, the paraffin, enclosed in a bag, is washed and pressed until the principal impurities are washed out; the final bleaching of the material is effected by heating the paraffin with fuller's earth. Another method of purifying the scale is by the use of naphtha, a process adopted at Addiewell and some other works. At Addiewell the crude paraffin is melted and run warm into a vessel of naphtha, sp. gr. ·750, which is in an underground room. To obtain the purified paraffin from this mixture a drum containing cold water is made to revolve in it: the paraffin crystallises on the drum and is scraped off, and then pressed in a cold hydraulic press. At Robin and Houston's works in Glasgow the warm paraffin is run into a tank of spirit, and the mixture is then pumped up into shallow vessels, when the paraffin solidifies and the solid matter is then subjected to pressure. The spirit is recovered by distillation with steam. In any case the purified paraffin requires to be bleached with animal charcoal or in some other way.

Manufacture of sulphate of ammonia.

Where the ammoniacal liquor is collected, it is converted on the premises into sulphate of ammonia. The process is in essential points similar to that adopted in the manufacture of the same salt from gas-liquor (p. 127). The liquor is distilled and the vapour is conducted into a closed box or tank containing sulphuric acid; the salt is either strained out as it forms, or the saturated liquor is evaporated down in open tanks by means of coiled steam pipes. When acid recovered from the "acid-tar" is used for this manufacture, and is coloured with the tar, as at the Oakbank Works, care is taken to keep the solution alkaline; the tar then rises to the top and the solution of the sulphate beneath it is siphoned off and evaporated down in the usual way.

Nuisance.

The processes I have described are apt to give rise to offensive effluvia, the odour being mainly that of the oily matters produced in the distillation. This odour, which is particularly disagreeable to some persons (it is so to myself), sometimes fills the air to a long distance to leeward of works where shale is distilled, even to the distance of a

mile or more. Where shale is not distilled, the odour, so far as I have observed, does not extend so far, but may be very disagreeably perceptible in the neighbourhood of the works. At the same time I have not heard of any complaints of injury to health from the effluvia. Shale distilling works are commonly located either in the open country or at some sufficient distance from populous places.

The following are sources which may contribute to the offensive effluvia from such oil or paraffin works as have been described :—

1. The drawing and subsequent ignition of the spent shale.
2. Inefficient destruction of the uncondensed gases by burning.
3. The steaming of acid-tar.
4. The burning of the tar.
5. Imperfect condensation of the products of distillation.
6. Leakages about works, and slovenly and dirty conditions of them.
7. The vapours and gases proceeding from the manufacture of sulphate of ammonia.
8. The steam evolved in the process of steaming either petroleum or paraffin out of casks.
9. Sulphurous acid and other offensive vapours arising when oil is blown during the acidifying process, or when paraffin is heated with sulphuric acid.
10. The vapour of the spirit used in purifying paraffin.

The nuisance from any one of these sources may be trifling, but it may not be trifling when several of these sources of nuisance are in operation together.

Prevention of nuisance.

1. The drawing and subsequent ignition of the spent shale, which still contains combustible carbonaceous matter, as well as some oil which the distillation has failed to extract. The only efficient remedies that I have seen applied to this source of nuisance are those in operation at the Straiton Works and at Addiewell. Of the two the former is preferable, since it is said that even the wetted shale, taken from the troughs into which the spent shale is discharged at Addiewell, sometimes fires when laid in a heap. When the shale is burned to an ash in the furnaces before removal, there can be no subsequent nuisance. Merely wetting the shale when it has been laid hot on a heap, is said not to prevent subsequent combustion with any certainty. Probably a more effectual remedy would be to draw it into water or to water it thoroughly immediately it is drawn, and then to spread it out on the ground to become cold before laying it in a heap, subsequently covering the deposit with earth patted down to exclude the air. In those cases, as in North Staffordshire, where the spent shale is intentionally burned in order to obtain an utilisable product, it may be suggested that a kiln of some kind, provided with means of conveying the vapours into a flue or chimney where they might be washed or consumed by fire, might be substituted for burning in a heap.

2. The nuisance from this cause is partly due to negligence in lighting the jets of uncondensed gas. The combustion, too, may not be sufficiently perfect to destroy all odour from the products of the burning. Hence it is preferable to burn the gas under a boiler or in a fire, and to discharge the products up the chimney shaft of the works. The heat is thus also utilised. I have shown how waste gas, first thoroughly cleared of condensable matters, is utilised in some of the shale works in Scotland.

3. Any nuisance from steaming the tar might be avoided by performing the operation in a covered tank, from which a pipe conveys away the steam to a condenser or to the chimney shaft of the works.

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4. The point to be sought in burning the tar is the obtaining of its complete combustion. This is obtained by the method in use at Addiewell.

5. When all the condensable products of distillation are not condensed there is a loss to the manufacturer. Nevertheless, the condensation is not always by any means so perfect as it ought to be. Addiewell again may be mentioned as a model work in this respect. Nowhere that I have visited are greater pains to avoid nuisance taken, and nowhere have the efforts made in this direction been more successful.

6. Leakages and slovenliness are also sources of loss. The litter and slop about some works that I have seen are, I am sure, quite unnecessary. At the best works nothing of the kind is seen. The surface of the ground is carefully drained into pits, where any spilt material collects on the top of the water and is utilised.

7. The remedies for any nuisance from sulphate of ammonia making are similar to those recommended in the manufacture of this salt from gas-liquor, namely, passing offensive gases evolved into a fire, after condensing the watery vapour.

8. The process of steaming out materials from casks might be conducted under a cover, as recommended in the case of similar steaming of casks of tallow or palm oil (1st Report, p. 211).

9. Sulphurous and other offensive fumes from the process of paraffin purification, &c. might (if producing nuisance) be conducted by pipes into the chimney shaft of the works.

10. The spirit process of paraffin purification, as usually conducted, is, on account of the danger of fire, as well as on account of its offensiveness, not adapted to works established in populous neighbourhoods. In such localities one of the processes in which the use of naphtha is avoided should be used in preference.

MANUFACTURE OF SULPHURIC ACID.

Establishments visited.

Establishments visited.

See lists of establishments given under the following headings:

Manufacture of Animal Charcoal,	1st Report	-	p. 230
,, Artificial Manures	ditto	-	p. 242
Distillation of Wood	2nd Report	-	p. 92
Manufacture of Oxalic Acid	ditto	-	p. 99
,, Alkali	3rd Report	-	p. 194
Copper Smelting,	ditto	-	p. 259
Distillation of Tar,	ditto	-	p. 137
Manufacture of Sulphate of Ammonia,	ditto	-	p. 127
Calcination of Arsenical Ores, &c.	ditto	-	p. 253

I believe I am correct in saying that there is no product of chemical art more extensively or generally used in chemical manufactures than sulphuric acid. It is essential to the majority of them. Hence it happens that chemical manufacturers who operate on a large scale find an economy in making it for themselves. Such manufacturers as operate on a small scale usually purchase what they require from manufacturers who make more than they need for their own use. There are but few manufacturers who manufacture sulphuric acid and nothing else.

Process of manufacture.

When sulphur is burned in the air it gives rise by combination with oxygen to sulphurous acid (SO_2); and in order to supply this with the additional atom of oxygen necessary for the production of sulphuric

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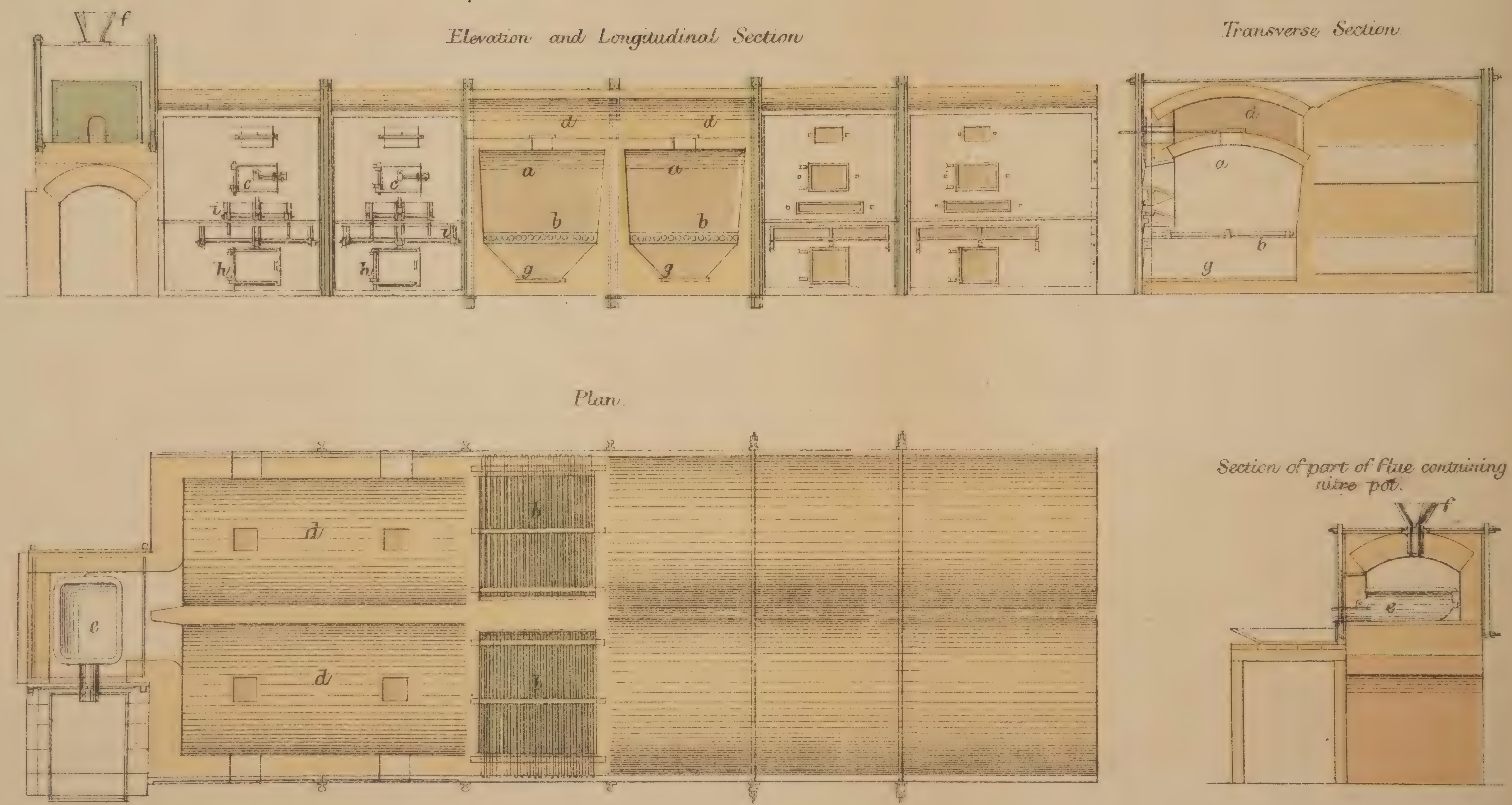
PYRITES BURNERS.

Scale, $\frac{1}{2}$ in = 3 Feet.



Sangerfield Lith. 22. Bedford St. Covent Garden

acid (SO_3), an oxidising agent is requisite, that is to say, something which will readily give up oxygen to the sulphurous acid when it is mixed with it in the gaseous state or merely moist with watery matter. Practically the higher oxides of nitrogen have been found the most convenient agents for this purpose. Nitric acid, NO_5, the highest oxide of nitrogen, in the form of vapour as it is given off by the action of sulphuric acid upon nitrate of soda (the cheapest of the nitrates), the process of preparation being easy, is, therefore, the oxide used. And it has this advantage, that, after it has given up a portion of its oxygen for the oxidation of the sulphurous acid, the lower oxide of nitrogen left, if air be supplied, resumes oxygen from the air, being converted thus into a high oxide such as NO_4; this is capable of again giving oxygen to another portion of sulphurous acid, and so the process will go on indefinitely. The oxide of nitrogen acts thus merely as a carrier of oxygen from the air to the sulphurous acid; it takes as it were with one hand and gives with the other.

Sources of sulphur.

Up to about 40 years ago little or nothing else beside crude Sicilian sulphur was used commercially as the material to burn for the production of the sulphurous acid; but now, although this is still used for the manufacture of sulphuric acid which is to be applied to certain special purposes, the necessities of trade and the fact that other manufacturing processes furnish a material capable, on being burned, of giving sulphurous acid in due quantity, have led to the use of other materials beside crude native sulphur; and now these materials have nearly, although not entirely, displaced it. The materials I have seen in use are pyrites or mundic (bisulphide of iron), and especially the cupreous pyrites which are principally imported from Spain, spent oxide of iron from gasworks, which contains a large proportion of free sulphur (p. 117), and, lastly, sulphuretted hydrogen proceeding from the saturators of sulphate of ammonia works (p. 134), or which has been liberated in the process of dissolving sulphide of iron in sulphuric acid in the manufacture of Venetian red on a large scale. Of these, the material in most common use is cupreous pyrites. It will be convenient, then, first of all, to describe the process of sulphuric-acid making from this material, as it is carried out at the most simple and elementary works, and subsequently to describe the modifications of apparatus requisite where crude sulphur or spent oxide are the materials burned.

Use of pyrites.

The cupreous pyrites used contain from 47 to 49 per cent. of sulphur combined with iron and with a small per-centage, 2 to 4 per cent. usually, of copper. An ore like this when once ignited will burn without fuel; that is to say, if air be duly supplied, the sulphur will combine with the oxygen of the air to form sulphurous acid which is given off as gas, while another portion of the atmospheric oxygen combines with the iron and copper to form oxides of these metals. In order to collect and utilise the sulphurous acid, the pyrites, broken up into lumps about 1½-inch diameter, are mostly burned in what is termed the pyrites burner or kiln. Plate XVIII., which is a drawing of one form of burner, will afford sufficient illustration. It consists of a chamber, constructed of fire-brick with a fire-brick arch *a*, in which the material is supported upon a grate of movable iron bars *b* so arranged that, from time to time, the burned pyrites can be discharged into a receptacle or little pit *g* below the grate bars, which pit is provided with a door *h* to close it in. The draught through the kiln can be regulated by the opening or closing of this door. The front of the kiln is faced with iron, and has in it a door or shuttered opening *c* at the level of the top of the charge within the kiln, by which opening fresh pyrites can be put in, and through which the process of combustion can be

The pyrites burner or kiln.

watched. The charge lies in the kiln to a depth of 14 to 27 inches, (the depth of the burner varying with the kind of ore used,) the bottom part consisting of ore completely or almost completely burned out, and the top of ore last introduced. Two rows of such kilns placed back to back (as shown in Plate XVIII.) constitute a "set" of pyrites burners. They are usually situated in an enclosed building, but sometimes in a shed or building open on one side to the air. Along the top of the set a fire-brick flue *d* runs, into which the sulphurous acid passes; the force which draws it into and along the flue being the exhaustion within the chambers arising from the condensation of the gases which takes place there, a force assisted or supplemented by the draught of the chimney which receives the escape gases from the vitriol chambers to be presently described. All the burners in a set being at work, they are recharged usually about every 12 hours, five or six cwts. of ore being then added through the charging door. They are charged in succession, with about an hour's interval between one and another, so as to obtain an equable and continuous supply of sulphurous acid from the row of burners. The proceeding is as follows:—The air is shut off at the bottom by closing the ashpit door, and then the small door *i* covering the ends of the grate bars is opened, and these are turned two or three times, leaving each alternate one out. The burned ore or "cinders" are thus made to fall through into the ashpit. This door having been closed, the charging door is then opened and the new charge is quickly thrown in and levelled, and then the door is closed and the ashpit door opened again to the necessary extent.

Mode of charging.

The nitre-pot.

From the pyrites burner the sulphurous acid at a high temperature is conducted to the vitriol chamber; and in the first part of the conducting flue are generally placed the nitre pots *e* which contain the mixture of nitre and sulphuric acid for the production of the nitric acid required for the process. They are iron pots, which now in the best works are arranged across the flue in such a way that they are bathed as it were in the hot gases from the kilns.* There are doors in the side of this flue opposite the nitre pots, by means of which they can be reached for removal if necessary, or for charging them without removal. In the best and most modern works the pots, of the shape indicated at *e*, are fixed, and are charged through a funnel *f* passing through the roof of the flue, and are discharged by a pipe or shoot passing through the side-wall of the flue.

The leaden chamber.

Thus what passes to the vitriol chamber is sulphurous acid, air and nitric acid vapour. The nitric acid quickly parts with some of its oxygen, however, to the sulphurous acid gas. The vitriol chamber is a large oblong chamber made of sheet lead, which is supported, while the shape of the chamber is maintained, by an appropriate framework of wood. In the best works there are several such chambers, commonly three or even four, provided, and the gases have to pass through them all in succession; from the last chamber there is an exit flue leading to the chimney, which produces the necessary draught through the chambers, and carries off waste gases. Steam (or spray) is thrown into all the chambers. The supply of steam has to be very carefully regulated through the aid of what are technically known as "dry glasses," that is to say, an

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* Mr. C. F. Burnard about four years ago patented (1875, No. 2873) a process by which he dispenses with the nitre pot, inasmuch as, instead of using nitric acid vapour, he throws a spray of a solution of nitrate of soda into his chambers. He has had this patented process in operation for some years at his manure works at Cattesdown, Plymouth. The sulphuric acid he makes, necessarily therefore, contains a little sulphate of soda, but the impurity is of no consequence where the acid is to be used for manure making.

arrangement by which acid dew condensing on the lead may be collected and from time to time drawn off so as to permit of its being examined by means of the hydrometer. In the first chamber, the first important reactions take place, and sulphuric acid formed unites with such steam as condenses there, and falls to the floor of the chamber. In this chamber there is always an excess of sulphurous acid, so that the colour of its gaseous contents does not indicate the presence of the higher oxides of nitrogen NO_3 and NO_4. Passing to the second chamber the reactions continue; but here, the sulphurous acid being less abundant, the colour of the gaseous contents is slightly yellow, and it becomes redder and redder as the gases pass to the last chamber, where the sulphurous acid ought to be all removed by conversion into sulphuric acid, the nitrous gases being in excess and oxidised into the highest oxide (NO_4) short of actual nitric acid. In this simple and elementary mode of making sulphuric acid, the gaseous contents of the last chamber pass gradually from it by the exit pipe into the chimney; and the waste gases, which thus pass off and are thrown away into the external atmosphere, are consequently the higher oxides of nitrogen (red nitrous fumes) with so much of the sulphurous acid gas as may have escaped conversion and condensation in the chambers, and a little sulphuric acid.

Use of "smalls."

But to return to the burners. The pyrites or mundic used for acid making is not always in such masses as will permit of its being calcined in such a burner or kiln as has been described. It is sometimes in a more or less powdery condition, when it is technically designated "smalls." Sometimes "smalls" are made up with clay into balls of sufficient size to be burned in the ordinary pyrites kiln, the balls being dried on the roof of the kiln before being burned; but other manufacturers prefer to burn "smalls" in some other kind of apparatus adapted to the calcination of such powdery substances. I shall have occasion to mention under the head of copper smelting (p. 226) the use of the Gerstenhöffer kiln for the calcination of poor copper ores rich in sulphur; but for this kiln the ore has to be crushed uniformly fine. I shall also have occasion to mention the use at certain copper and tin works of a muffle furnace for the same purpose (pp. 268 and 258). Other modes of burning "smalls" by themselves have been tried and are still in use in some works.*

Use of crude sulphur.

Crude sulphur is usually burned in low-arched chambers of fire-brick having a flat floor formed by a cast-iron plate, and it is customary to place the nitre pots on the same floor. Part of the sulphur is very apt to sublime. With a view to prevent this to some extent, an air channel is commonly constructed beneath the floor-plate so as to keep its temperature down. The admission of air to the burner has to be carefully regulated. With this ordinary form of burner the burning is not continuous, and after each charge of brimstone has been burned the ashes have to be raked out before a fresh charge is introduced. Various contrivances have been invented for continuous feeding and for procuring the combustion of the sulphur which sublimes. A description of the best of these is given in Dr. Lunge's book (*op. cit.*, p. 140).

Use of spent oxide from gasworks.

Spent oxide of iron from gasworks (p. 117) is first washed to get out the ammonia it contains, that is, if it contains sufficient ammonia (say 5 to 10 per cent.): otherwise it is at once put into the kiln for burning. Sometimes it is burned in an oven like that used for burning crude sulphur, but ordinarily in horizontal fire-brick flues about 10 feet long, 20 inches wide, and 9 inches high, arranged in rows one above another.

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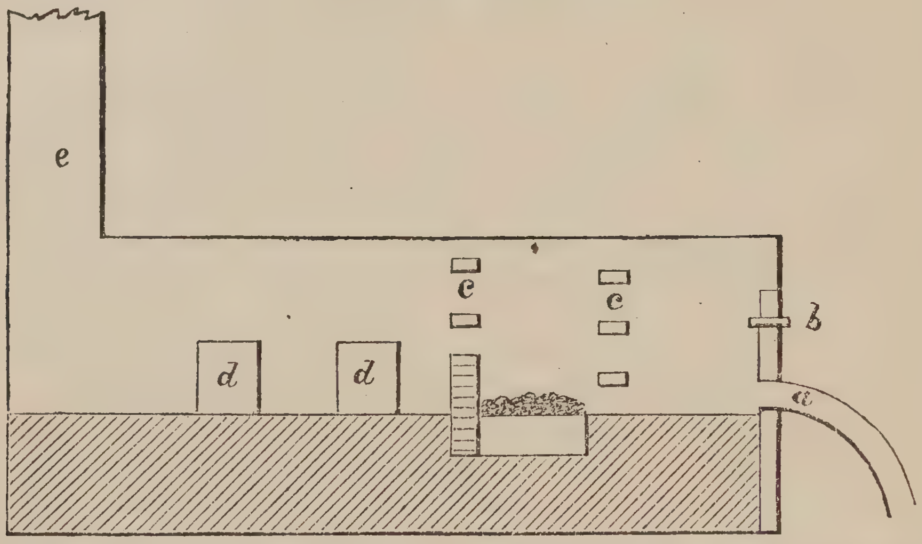
* For a description of these see "A Theoretical and Practical Treatise on the Manufacture of Sulphuric Acid and Alkali," &c., by George Lunge, Ph.D., F.C.S., Van Voorst, 1879, Vol. i. p. 186.

On the face of the set at one end of each flue is a shuttered opening, the shutter having a slit in it for admission of air. At the other end, behind the set, the flues communicate with a common flue in which the nitre pots are placed, and in which there are doors by which access is had to them. There are varieties in the mode of arranging this main flue observable at different works.

Use of sulphuretted hydrogen.

The following rough diagram, Fig. 24, illustrates the burner used at Illingworth's Sulphate of Ammonia Works at Frizinghall, for utilising the sulphuretted hydrogen given off from the saturator (p. 130). I am indebted for the diagram to Mr. Edwin Hunt, of Wednesbury, whose father,

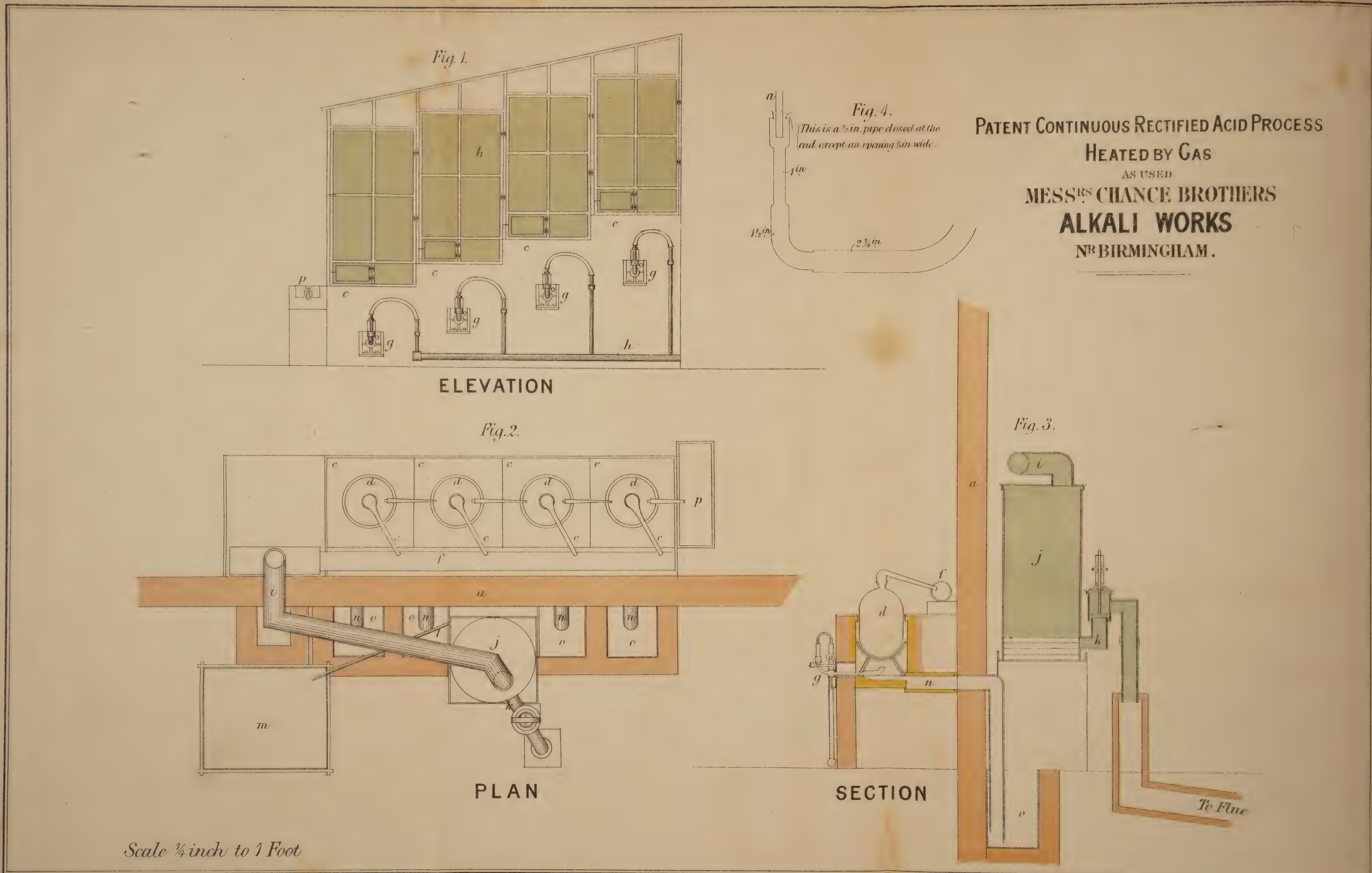
Fig. 24.



I understand, contrived the burner. It consists of a fire-brick chamber about 12 feet long, 3 feet deep, and $4\frac{1}{2}$ feet wide, into which at one end the gas, which has been first carefully dried (p. 133), is admitted by the pipe *a*. In the wall there is a small air opening *b* furnished. Some pigeon-holed walls *c* are provided within the chamber. The nitre pots are situated within the chamber at *d*, and there are openings, closed by doors, for obtaining access to them. The sulphurous acid gas, steam, and nitric acid produced pass off by a flue *e* at the further end of the combustion chamber to the vitriol chamber. The gas once ignited and the chamber well heated, the combustion proceeds satisfactorily; but when the work is not going on the heat of the chamber has to be otherwise maintained, and for this purpose at such times, as for example on Sundays, a small coke fire is kept up in the fireplace. The Frizinghall Works have now passed from the hands of Mr. Illingworth into those of Messrs. Spence and Steuart, who are carrying on the same process at Nechells, near Birmingham. The sulphuretted hydrogen burner in use there is virtually similar to that figured above, but some modifications have been made in it, removing the fire-place to a position just below the entrance of the gas pipe *a*, and the nitre pot to a position at the far end of the chamber, where access is obtained to it by an opening closed by means of a plate during working.

Concentration of sulphuric acid.

Where no towers are in use, acid is drawn from the vitriol chambers at sp. gr. from 1·35 to 1·50, and for many purposes these densities suffice. But for other purposes the acid has to be concentrated. Where there is no Glover tower, this concentration is first effected by evaporating or boiling it down in a lead-lined tank, mostly open, heated either by a fire beneath or by erecting it on the top of a pyrites burner. But inasmuch as sulphuric acid when it arrives at a sp. gr. of 1·70 rapidly dissolves lead, further concentration, or as it is then sometimes termed "rec-



Dangerfield Lith. 22 Bedford St. Covent Garden

tification," to sp. gr. 1·85, the density of mono-hydrated acid (HO, SO_3), has to be effected in vessels on which the strong acid will not act chemically. Vessels of glass or platinum are therefore used for this purpose. Platinum, being expensive, is not so much used as glass.

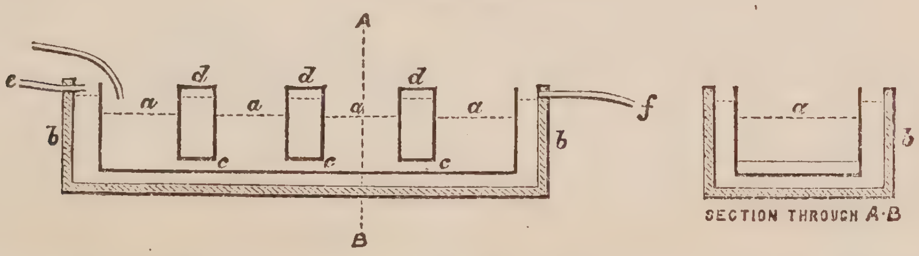
Rectification.

Rectification in glass.

In chemical works where the acid is rectified, a separate house is usually set apart for the purpose. The acid is introduced into large glass retorts which are set each over a separate fire maintained beneath it; and in a house of this kind a long row or set of such fires (or more than one row) may be seen arranged in a bank, usually at the sides of the house, each with its retort of acid boiling above it, the long beaks of the retorts being directed towards the wall, where they are introduced loosely into apertures in a wide leaden pipe intended to receive and conduct away such acid vapours as are given off. The vapours condense in this pipe, and the condensed acid, which is weak, is received in an appropriate vessel and either returned to the vitriol chamber or to the first concentration pan. At other works what is termed the "continuous" process is adopted. Retorts are used of the shape figured in Plate XIX (*d.*), and a series of, say, four retorts is set, as represented there, in a row, each retort being at a little lower level than the preceding one in the series. At the works of Messrs. Chance at Oldbury, to which Plate XIX. refers, the glass retorts are about 32 inches high, and about two-thirds of the distance from the bottom there is an overflow glass tube which conveys the acid, partly concentrated in the first retort, into the second retort, and so on to the fourth, from which it flows away to a cooler. A funnel reaching nearly to the bottom, and introduced between the overflow pipe and the neck, conveys a gentle flow of acid for concentration into the first retort of the series. The acid flows from the last retort at a temperature (at the time of my visit) of 800° Fahr.: it is therefore necessary to cool it before it can be allowed to flow into the carboy. This cooling may be effected in various ways, but at Messrs. Chance's works a leaden cooling box or trough is used, of which Fig. 25 is a rough diagram. Indeed, it is rather a series of leaden boxes *a a* immersed in a wooden trough *b*, through which water

at Messrs. Chance's works.

FIG. 25.

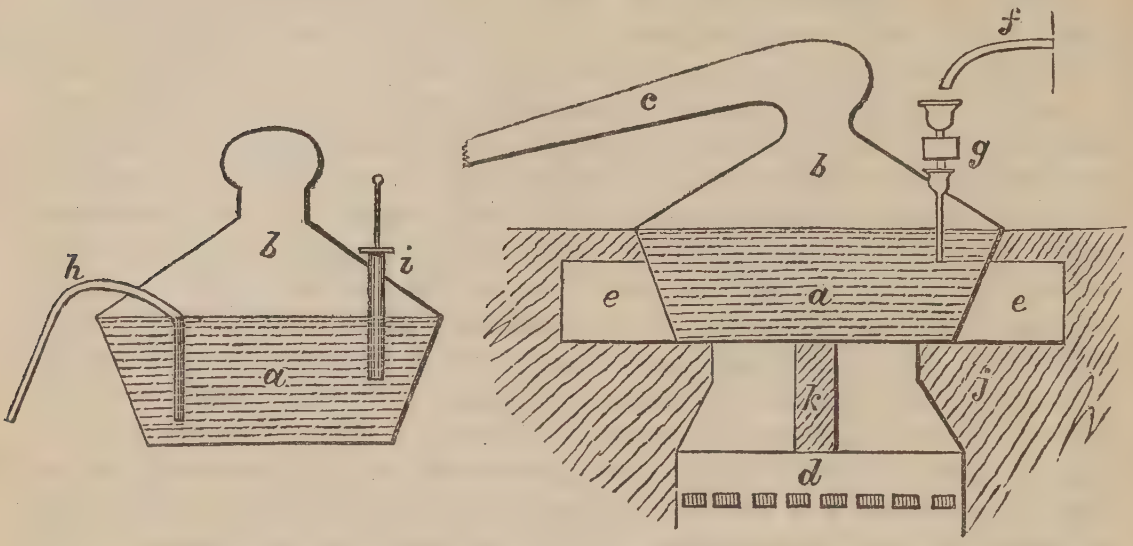


flows constantly, and communicating at the bottom by flat passages *c*, of the same width as the boxes; the upper edge of the boxes being kept in place by a little sheet of lead *d* passing between them. Each box therefore is surrounded by water which enters by the pipe *c*, and leaves the wooden trough by the pipe *f*. The acid is siphoned off from the last box into the carboy at a temperature (at the time of my visit) of 110°.

Fig. 26 is a rough diagram showing an ordinary arrangement of a platinum still for rectifying sulphuric acid. The following description is abridged from Dr. Lunge's work, where (p. 526) a complete drawing is to be found. The whole lower part *a*, which is continued about 1 inch above its greatest diameter, is made in one piece. The upper part *b*, narrowing towards the head, is gold soldered or soldered with platinum. The still is heated by the fire-place *d*, over which it is supported by the circular wall *j* and a middle wall *k*. The flame circulates in the flue *e*

round the sides of the still. The acid runs continuously from *f* into a feeding funnel *g*, which dips a little way into the acid within the still,

Fig. 26.



the level of which is indicated by a float *i*. The strong acid is continuously drawn off by means of a platinum siphon *h*, which reaches nearly to the bottom of the still. The level is maintained as shown in the diagram by careful regulation of the inflow and outflow of acid so that one shall just balance the other. The acid and steam which pass off by *c* are carefully condensed. At gold refineries which I have visited the lower part of the still is made of cast iron on account of cheapness of construction, and the upper part of platinum, iron not being acted upon by acid of the strength at which it is introduced at these works, namely, 60° Beaumé (p. 299).

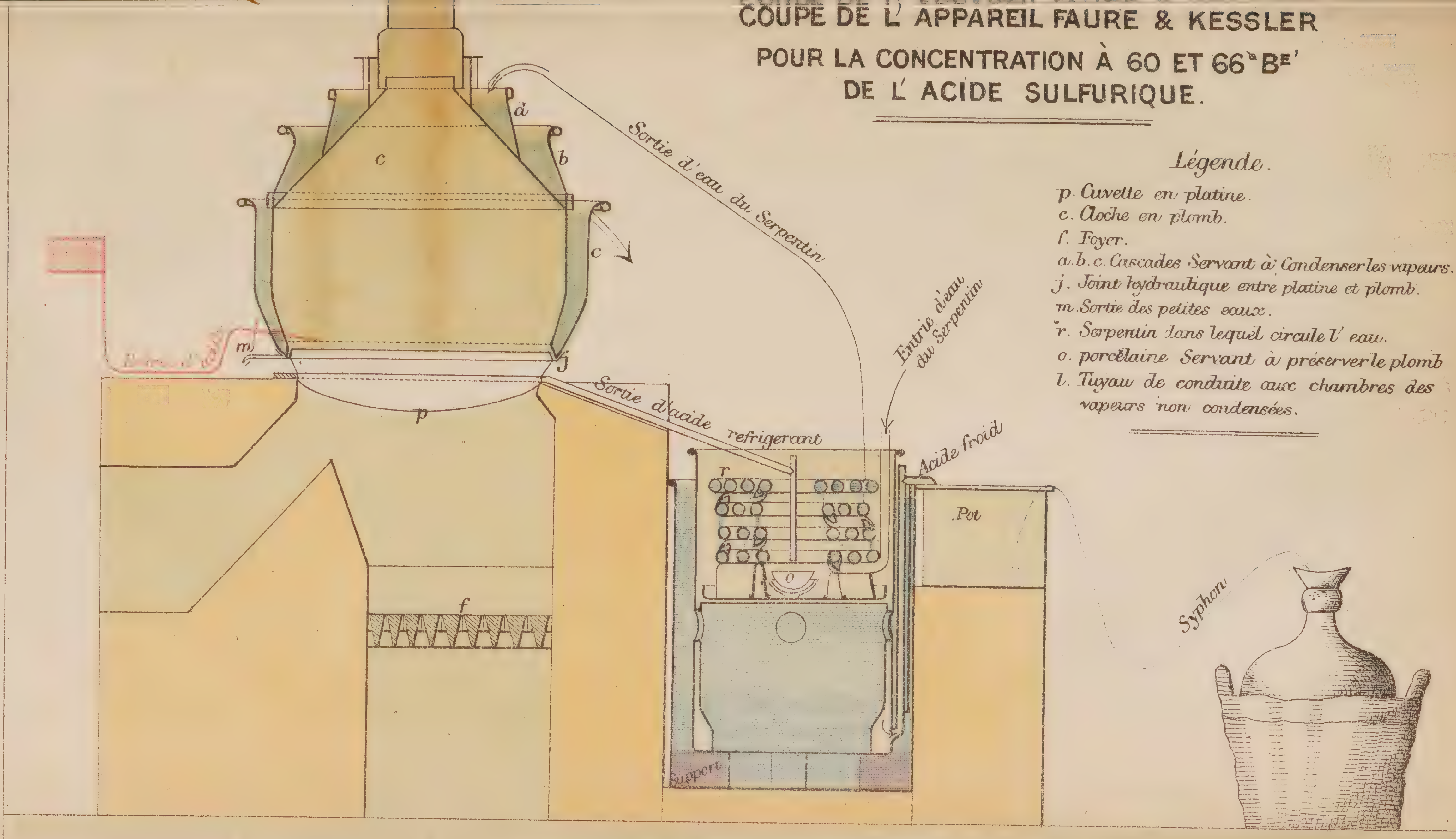
Rectification in platinum.

Faure and Kessler's apparatus.

At the works of James Muspratt and Sons in Liverpool, platinum vessels are used to rectify the acid, the arrangement adopted being that of Messrs. Faure and Kessler's patent apparatus, by which the acid vapours given off are condensed and collected. It consists essentially of a shallow platinum basin surrounded by a rim deep enough to constitute a water lute, and of a leaden dome or hood, from the summit of which a pipe conveys away any vapours which have to be discharged. The dome and adjoining part of the pipe are jacketed, and cold water flows through the interval between the dome and its jacket. The lower edge of the dome dips into the rim above mentioned. The pan is heated by a fire beneath, and the acid vapours that arise are condensed on the inner surface of the hood or dome, and the condensed liquid runs down into the rim and lutes the dome in this situation. There are the necessary pipes for introducing acid and running it off from the pan, and for running off weak condensed acid from the rim or luting channel, and also for supplying cold water to the jackets of the apparatus. Plate XX. shows in section the arrangement of Messrs. Faure and Kessler's improved apparatus. I am indebted to the patentees for the drawing of which it is a copy. It will be observed that the head or cover *c* is jacketed by a jacket in three tiers, the water flowing from the top to the middle, from this to the lowest tier, and from this away for discharge. The weak acid condensed on the inside of the cover runs down into the groove *j*, into which the edge of the hood dips without touching the bottom, and thus forms a hydraulic lute. This weak acid runs off by the pipe *m*. In the drawing the supply of the jacket is indicated as derived from the water which has passed through the coiled pipe of the refrigerator, but it may be

To face Page 174.

COUPE DE L' APPAREIL FAURE & KESSLER POUR LA CONCENTRATION À 60 ET 66° Bé DE L' ACIDE SULFURIQUE.



Légende.

p. Cuvette en platine.
c. Cloche en plomb.
f. Foyer.
a. b. c. Cascades Servant à Condenser les vapeurs.
j. Joint hydraulique entre platine et plomb.
m. Sortie des petites eaux.
r. Serpentin dans lequel circule l' eau.
o. porcelaine Servant à préserver le plomb
l. Tuyau de conduite aux chambres des vapeurs non condensées.

Dangerfield Lith. 22, Bedford St. Covent Garden.

supplied independently. The refrigerator represented in the drawing is a cylindrical leaden vessel, the lower part of which is annular, the cavity of the ring being widened a little at the bottom for the sake of stability. The upper half, which is not annular, has coiled within it pipes which convey cold water. The whole of this leaden vessel stands in a cylindrical vessel filled with water, the annular lower portion of the leaden vessel thus having cold water on both sides of it. The acid obtains its first cooling in the upper part, and is further cooled in the lower annular portion, from the bottom of which a pipe rises and conveys the cold acid into a receiver.

Nuisance.

The nuisance complained of as arising from sulphuric acid works is the discharge into the atmosphere of sulphurous, sulphuric, and nitrous acid fumes. It is a nuisance perceived sometimes in the immediate neighbourhood of the works, but sometimes at a distance of half a mile or more from them; the distance at which the fumes may be a nuisance depending not only upon the weather, but also upon the conformation of the country, &c., as explained in the introductory part of my first Report. The fumes are not only complained of as disagreeable, but also as suffocative, irritating, and as producing cough.

The disagreeable fumes may proceed either from a low level or from the chimney shaft of the works. Those arising from a low level are mostly fumes of sulphurous or sulphuric acid; those from the chimney are mostly nitrous fumes, which may be even visible, from their red colour, as they rise and pass away from the chimney.

High-level nuisance.

The escape of acid fumes from the chimney is sometimes very considerable. In fact where absorbing and concentrating towers (described later on) are not used (and this is the case in most small works and in some works also which cannot be called small), a very large per-centage of the nitric acid of the nitre used passes off by the exit from the chambers; and, of that which does not so pass off, a moderate but variable quantity remains as nitrous acid (NO_3) in the chamber acid. And it is to be observed that under these circumstances, where no economy of nitrate is practised, the quantity of that substance used is very greatly in excess of what is used where towers are employed. In three instances mentioned by Mr. G. E. Davis (Journal of the Chemical Society, July 1878, p. 615), the quantity of oil of vitriol made per week and the quantity of nitrate used to make it were severally 50 tons of acid and 34·5 cwts. of nitrate used; 90 tons, and 50 cwts. of nitrate; 45 tons, and 28 cwts. of nitrate; whereas in three other works where towers are employed Mr. Davis found 140 tons of oil of vitriol made with the expenditure of 21 cwts. of nitrate, 100 tons with 32 cwts. of nitrate, and 120 tons with 42 cwts. of nitrate. In addition to nitrous compounds, sulphuric and sulphurous acids escape from the chambers.

In illustration of closeness of working with towers so far as sulphur is concerned, I may mention that Messrs. Chance of Oldbury, who keep a strict daily record of loss from the chimneys connected *only* with their sulphuric acid plant and receiving nothing from their alkali plant, have given me the following figures showing their average loss from four such chimneys in a year's workings; viz.,—

Chimney	C.	- 1·21	per cent. of all the sulphur burned.		
„	F.	- 0·80	„	„	„
„	G. No. 1,	1·11	„	„	„
„	G. No. 2,	0·96	„	„	„

One cause of chimney escape is too small chamber space for the quantity of material calcined. The chamber space at different works varies from 16½ cubic feet to each pound of sulphur burned in 24 hours,

which is too low, to 27 cubic feet, which is regarded as rather an excessive space. Another cause is the use of too little nitre, which results in part of the sulphurous acid not being oxidised, but passing off as such by the exit pipe.

Low-level nuisance.

The following may be mentioned as the sources of nuisance proceeding at a low level from sulphuric acid works :—

1. From the kiln.

1. Leakages from the burners or kilns. Sometimes, and I think in a considerable proportion of instances, these leakages arise from dilapidations in the brickwork of the kilns and flues, from which sulphurous acid is sometimes lost in sufficient quantity to render it almost impossible for men who are sensitive to such fumes to remain many minutes in the burning-house. Leakage sometimes occurs at the feeding and other doors, even when they are closed, and in this latter event, there is abundant escape from the feeding doors when they are opened for the purpose of charging. This is usually the result of defective draught. Too rapid a draught is not desirable, since it would carry in too much air with the acid gases into the chamber and hurry them through too speedily; but the draught may be too small, and then there will be a tendency of the gas generated within the burner to pass out at the doors and chinks about the burner. Dr. Lunge (*op. cit.* p. 179) writes thus on this subject: "Insufficiency of draught, if very con-" siderable, will be easily recognised by the gas blowing out of all the " joints of the burners, and especially coming out in force whenever " the working doors or bottom door are opened. . . . It may be " assumed that the draught is just right, if, on opening the small slide " in the working door, neither gas nor flame issues from it, nor, on the " other hand, the flames inside the burner perceptibly tend towards the " draught hole. They ought to rise up perpendicularly and quite " steadily, and on opening the door they may even tend slightly towards " it." The draught upon the kilns is due to and dependent upon circumstances thus explained by Dr. Lunge (*op. cit.* p. 327). "The hot gaseous mixture" (proceeding from the kilns) "in itself contains " the conditions for causing a draught, since it is much lighter than the " air, and thus will always have a tendency to rise from the burners to " the chambers." There is also "another potent source of draught, viz., " the formation of liquid sulphuric acid within the chambers from the " mixture of the gases, which must necessarily have an aspirating " action, although not only from the burners, but from all sides. Along " with these two sources of draught furnished by the essence of the " acid-making process itself, there must always be another arrangement " for causing further draught, especially because otherwise the current " of gas could not be turned into the required direction." Preferentially this other arrangement is a chimney, which of course "to do its work " must be higher than the chambers"; but "whether the draught be " produced by a chimney or by an open pipe, there must always be " some contrivance for regulating it. At many works this is done by a " simple damper," but other contrivances are described in Dr. Lunge's work. It is clear therefore that bad working of the chambers and imperfect or irregular condensation within them may be one cause of serious escapes from the burners, and another cause may be bad regulation of the chimney draught. With respect to the former of these causes Dr. Lunge (p. 345) says "The regulation of the steam is one of the most important parts of chamber management."

So much for the more serious escapes; but even when the apparatus is working well, sufficient gas to occasion nuisance may issue from the feeding doors when they are opened for the charging of the kilns. This is mostly due to the fact that the air which enters the burners

during the combustion of the ores has a tendency to enter not only at the place where special provision for its entry is made, namely, at the ashpit door, but also at every chink or crevice about the kiln, as, for instance, round the edges of the several doors on the face of the kiln, if these doors do not fit perfectly closely. Altogether the draught through a well working kiln is so slight that on opening the feeding door there is nearly as much tendency for the gas to escape from it into the kiln house, as for it to pass into the flue. The merest trifle of pressure or aspiration on one side or the other may determine which way the gas will go. Escape under those circumstances will arise if the workman, before opening the feeding door, is not careful so to close up all other avenues of entry for air into the kiln, that when the door is opened the only air that can enter the kiln shall be through the open door; in this case and under such proper management the entrance of air by the open door prevents the exit of gas by the same channel. The tendency to escapes by the feeding doors is favoured, as in the case of lampblack burners (p. 150), when a draught of air or wind crosses the feeding doors. The liability to the last-mentioned circumstance is one of the evils attendant on neglect of placing the burners within an enclosed building. When the nitre chamber is opened, either to charge the pots or to stir their contents, an escape of gases is very apt to occur.

2. From vitriol chambers.

2. Leakages from the vitriol chambers. These occur from the eventual corrosion of the lead of which they are made: the corrosion chiefly occurs at the joints and strips of the sheets. The fumes which escape under these circumstances contain more or less of all the acids that exist at the time in the chamber.

3. From concentrating acid.

3. The concentration of chamber acid in an open tank gives rise to vapours of sulphuric acid, which come off mixed with the steam, and of sulphurous acid also, when (as is sometimes the case) the acid contains sulphurous acid, or when there is any amount of organic matter present, as for instance when acid from aniline works (p. 160) is concentrated. Nitrous fumes are also evolved when the chamber acid under treatment contains nitrous compounds.

4. From rectifying acid.

4. But the most atrocious nuisance from vitriol works occurs when, during rectification, one of the glass vessels containing concentrated acid breaks. There is then danger to the workman also. The strong acid running into the fire beneath is suddenly converted into vapour, partly sulphuric acid and partly sulphurous acid; the vapour fills the house, so that it is impossible to remain in it, and escapes by the ventilating openings into the external atmosphere. Such an accident occurs very readily; a short sharp draught of cold air entering by the doorway or window, and impinging upon the hot retort, may at any time occasion a crack; and when a fracture does occur it is certain to create an outcry from neighbours. Fortunately the resultant nuisance is not of long duration.

Prevention of nuisances.

1. Of nuisance from chimney.

As to the remedies applicable for the prevention of these nuisances.— 1. The nuisance arising from acid escapes by the chamber exit is altogether avoidable by the due use of the "Gay Lussac or absorbing tower," for the due and economical application of which the "concentrating or Glover tower" is essential. This, then, appears to be the proper place in this Report to describe these towers and their use in the process. In the Gay Lussac tower the gases escaping from the last chamber are deprived of the nitrous compounds they contain by absorption by means of strong sulphuric acid. The chief objects of the Glover tower are to concentrate chamber acid cheaply and sufficiently for this use of it, and at the same time to deprive the sulphuric acid of the nitrous compounds it has taken up either in the Gay Lussac tower or in the chambers, and to

return them to the first chamber for use again as a carrier of oxygen. It is in this way that the economy of nitre before mentioned (p. 175) is mainly effected.

The Gay Lussac tower.

The Gay Lussac tower is a leaden scrubber packed with coke, of sufficient height and capacity for the work that it has to do. By an appropriate distributor, which need not be described, concentrated sulphuric acid deprived of its nitrous compounds by the Glover tower, collected and cooled in appropriate vessels and forced up to the top of the Gay Lussac tower, is run down over the coke. The gases from the last vitriol chamber, drawn by the chimney, pass in below, pass up through the coke, and are discharged above by an exit flue into the chimney. At Messrs. Bealey & Co.'s works at Radcliffe, near Manchester, a second smaller Gay Lussac tower is provided, by means of which a second scrubbing with concentrated acid is effected, and, as Dr. Hewitt tells me, with the best results.

The Glover tower.

The Glover or concentrating or "denitrating" tower is constructed much in the same way. It is interposed between the burners and vitriol chamber, so that the hot gases, sulphurous acid and nitric or nitrous acid, pass up through it on their way to the chamber. This also is essentially a coke tower, the following description of which, by Mr. Glover himself, I extract from Dr. A. Smith's last report. I may premise that the principle of the tower lies in this, viz., that when strong sulphuric acid charged with nitrous compounds is mixed with water, the latter (or most of the latter) are immediately disengaged; the colour of the mixture becomes of a more or less deep red, and, according to the temperature to which it is then exposed, nitrous fumes are more or less abundantly given off. Weak sulphuric acid acts in the same way as water:—"The Glover "tower consists of a leaden tower (of size proportionate to the work to "be done) lined throughout with good fire-brick. An arch is turned "between the two sides inside the lining about 6 feet from the bottom. "This arch carries the packing of the tower, and allows the gases "from the pyrites kilns to pass up and through the packing. The "packing consists of flints or fire-brick for the first 6 feet, to diminish "the danger of fire. The remainder of the packing is of hard coke. "The gases from pyrites kilns enter the tower below the arch at a "temperature of 500° or 600° Fahr., varying according to the quantity "of pyrites burned into each tower. During its passage up the tower "through the packing, the gas (hot) meets a descending stream of mixed "acids, viz., chamber acid at about 120° Tw. (sp. gr. 1·60), and the "acid from the Gay Lussac tower at about 146° Tw. (sp. gr. 1·73). "The contact of the weak chamber acid with the nitro-sulphuric acid "from the Gay Lussac, aided by the presence of the hot sulphurous "acid from the pyrites kilns, completely denitrates the nitro-sulphuric "acid, the nitrogen compounds of which are carried by the sulphurous "acid from kilns into the chambers at about 170° to 180° Fahr. The "mixed acids, after being in this way thoroughly denitrated, issue "from the Glover tower at a temperature of 280° to 300° Fahr., and a "strength of 150° to 154° Tw. (cold), (sp. gr. 1·75 to 1·77). This is "now ready for the Gay Lussac tower (where it is now forced), and "absorbs again in the Gay Lussac the nitrous compounds leaving the "chambers, after having done their work there. We call the acid now "nitro-sulphuric, which is again forced up to the top of the Glover "tower and denitrated as before. The acid issues *from* the Gay Lussac "at 148° to 146° Tw. (cold) (sp. gr. 1·74 to 1·73). Not only does the "strong acid put *on* to the Gay Lussac *absorb* the waste nitrogen com- "pounds issuing from chambers, but it makes sulphuric acid in the "tower itself, there being always a portion of sulphurous acid escaping

" from the chambers, even when there is a large excess of nitrous acid " or other compounds of nitrogen, which is converted into sulphuric " acid in the interior of the Gay Lussac. You will see the saving of " nitrate of soda, when the towers are properly worked, must be con- " siderable, being in fact from 50 to 70 or 80 per cent." (12th and 13th Reports, p. 52). For the sake of clearness let me repeat that, where towers are used, the course of the gases is this, from the burner to the Glover tower, where they meet coming down nitro-sulphuric acid in which the nitrous compounds have been loosened by admixture with weak acid. These the heat of the gases and the chemical action of the sulphurous acid present separate, and the gases carry them away with them to the vitriol chamber, where they act again as they did when originally introduced from the nitre pots. After traversing the several chambers, in the passage through which the nitrous gases come gradually to form a larger and larger proportion of the mixed gases within the chamber, they pass from the last chamber (where nearly all but nitrous compounds have disappeared from the mixture) to the Gay Lussac tower, where the waste gases are absorbed before the final issue of what theoretically would be wholly innocuous gases by the chimney. Arguing from such a statement as this, it might be gathered that, since the nitrous compounds are thus worked round and round, no nitre whatever would be required to be used after the circulation described has been once established. But actually in working, even with towers in the best-managed works, there is a loss of available nitrous compounds, rendering the continuous use of fresh nitre necessary.

Dr. Hurter, of Gaskell, Deacon, & Co.'s works, has furnished a paper on the causes of this loss, basing his calculation on the carefully-observed results of working at several of the largest English alkali works. He divides the losses into mechanical losses and chemical losses. The losses from mechanical causes he enumerates as *a*. nitrous acid (NO_3) escaping with the exit gas, in quantity which he estimates as equivalent to 10·5 per cent. of the nitrate used; *b*. nitrous acid remaining in the Glover tower oil of vitriol in consequence of imperfect denitration, which at Deacon & Co.'s works hardly ever reaches six per cent.; and *c*., nitrous acid leaking from the chambers, which is trifling in amount, but for which he allows five per cent. The remaining loss he regards as chemical, and believes it to be due to the reduction of the higher oxides of nitrogen to either nitrous oxide, (NO) or nitrogen. The place where this loss occurs and the precise mode of its occurrence are subjects yet in controversy. (Chemical News, April 18, 1879, p. 170.)

The Glover tower is not ordinarily found in use at works where brimstone acid is made. One reason assigned is that this acid is mostly used for the manufacture of sulphate of ammonia, the colour of which is injured by very small admixtures of iron, and a little iron is always carried down from the Glover tower. But there are several makers of brimstone acid on a large scale who have adopted the tower successfully.

At some small works that I have visited, the gases which escape from the chamber are passed through a small leaden tower packed with coke or flints, into which steam is thrown. This may serve to condense any sulphuric acid that might otherwise escape, and to carry it back to the chambers, but can have little other beneficial result.

Sometimes the fault lies in the incapacity of the chambers to deal with the amount of gases introduced into them. In that case the remedy against the chimney nuisance lies in increasing the size or number of the vitriol chambers.

2. Of low-level nuisance.

2. As respects the low-level nuisance.—1°. Constant watchfulness is necessary to note, and to obviate by due repairs, leakages by dilapidation

about the brickwork of the burners. Where there is a serious issue of gas causing nuisance from the feeding openings and chinks about the burners, attention should first be directed to the improvement of the draught through the apparatus. It ought to be so thoroughly under control that it can be adjusted either by way of increase or diminution to varying conditions, whether of the weather or of the working. A deficient draught should draw special attention to the condensation taking place in the chambers, and to the quantity of steam which is being introduced. "The regulation of the steam," Dr. Lunge says, "should always be taken in hand by the superintendent himself." The rules for its due regulation are given in Dr. Lunge's work (p. 346). It is always desirable to protect the burners from the wind by enclosing them within a building.

A writer in the Chemical News, (May 23rd, 1879, p. 226,) says that he has found the following simple plan of proceeding efficient against the minor nuisance of escape from the feeding doors which may take place even when the chambers are working well. "It was simply to close all the "ashpit doors before the door of the furnace to be charged was opened. "The necessary draught being forced to enter through the only open door "entirely prevents the escape of gas, and the workman has only to open "the ashpit doors again to admit the proper amount of draught to each "furnace." "This plan," he adds, "I found to have the advantage of "making the furnaces burn more regularly, as the fireman, from having "to open and close the ashpit doors oftener, had his attention directed "to them, and so the draught was better regulated." Mr. C. Norrington has recently patented (1878, No. 4,131) a mechanical arrangement for effecting the simultaneous opening or closure of all the ashpit doors on the same side of a set of burners. The ashpit doors are made air-tight, and so as to slide laterally in frames, and are all connected together on one system of rods moved by gear work so arranged that one man can with ease move every door at once and open or close them to the extent desired. This arrangement, when I saw it in operation last July at Plymouth, was working efficiently. The ashpit doors being all closed, I found that even two charging doors might be left open without any escape occurring into the kiln house. There is nothing new in the construction of the various doors so that they shall slide laterally upon accurately planed surfaces. It is the best mode of constructing doors, since, if the planed surfaces be kept smooth and clean and are free from corrosion, no air can enter the kiln round their edges, and the due entrance of air by the ashpit door alone, theoretically its proper mode of entrance, can be practically maintained; and this is really the main point to be gained, since, when gained, the only other thing to be attended to is the regulation of the openings at the ashpit doors. It is one of the evils of hinged doors that it is practically impossible to close them so perfectly that no air will enter by the edges. The only certain way of preventing this occurrence is by luting round the edges with clay or some other appropriate lute. This is what is now done at James Gibbs & Co.'s works at Victoria Docks, where formerly the escapesfrom the feeding doors were a source of nuisance. In place of a sliding door to the ashpit, a cast-iron mouthpiece, Plate XXI., Figs. 1, 2, *a*, has been provided in this situation, and bolted on to the front; it is fitted with a cast-iron lid *b* on the groove and tongue principle, which is luted on with some soft substance. In this lid there is an oblong opening *c*, with slide cover for regulating the admission of air to the kiln: the air, therefore, can only enter by this opening. When a charging door is about to be opened, this opening and the openings of the other mouthpieces on the same side of the set are closed

ARRANGEMENT OF ASHPITS AND NITRE POT OF PYRITES KILNS AT JAS. GIBBS & COS. WORKS, VICTORIA DOCKS.

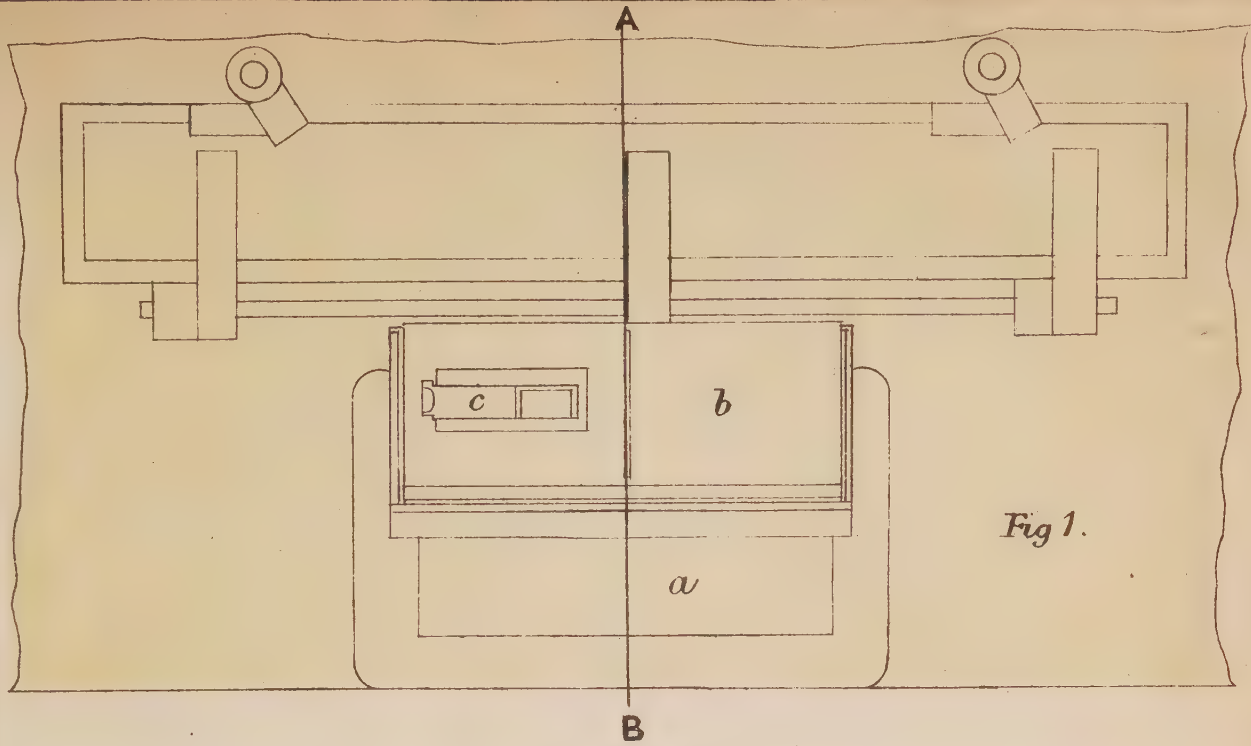


Fig 1.

Elevation.

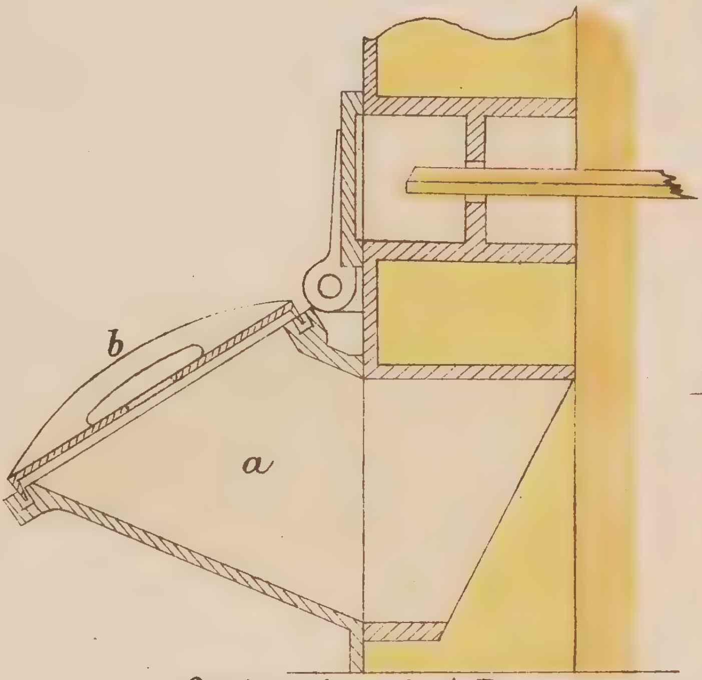


Fig 2.

Section through A.B.

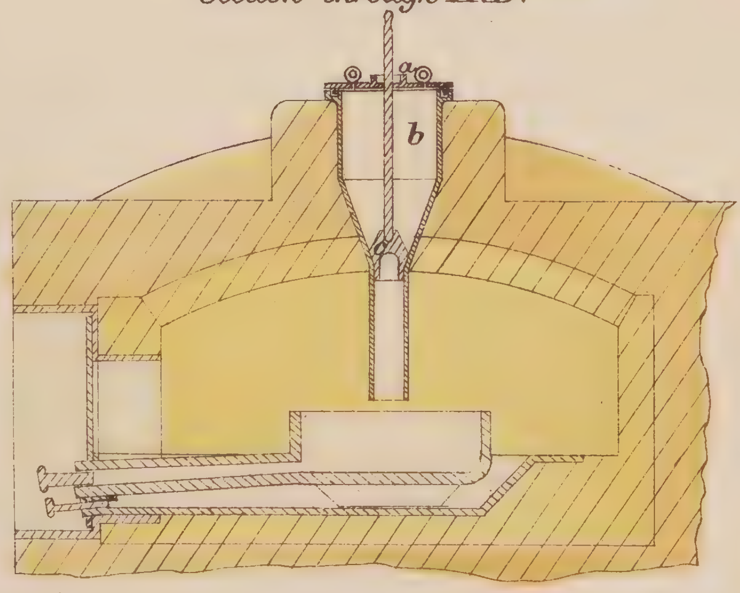
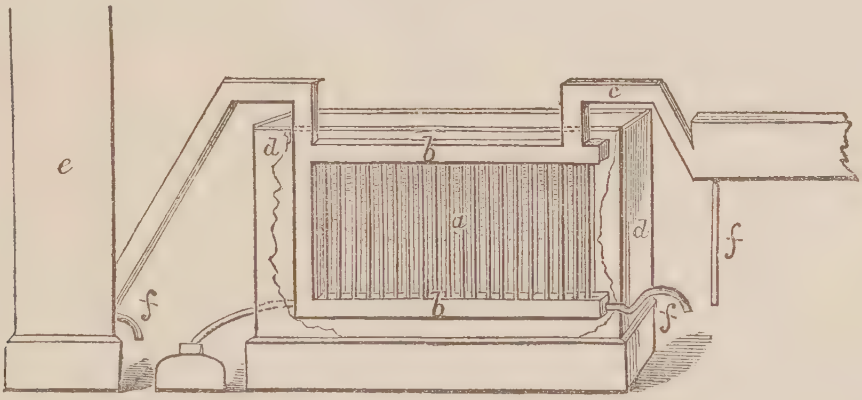


Fig 3.

DANGERFIELD. LITH. 22. BEDFORD ST. COVENT GARDEN.

by means of the slides, a proceeding which does not occupy half a minute. This arrangement has been effectual in obviating the nuisance. The escape of gas during the charging of the nitre-pot may be obviated by the same means by which the escape from the charging-doors of the kilns is obviated, namely, by shutting off or sufficiently reducing for the time the admission of air to the burners on that side of the set: or the charging funnel may be trapped as shown in Plate XXI., Fig. 3, where *b* is a cast-iron funnel built in the crown of the flue, and fitted with a cover *a*, and a plug *c*, the spindle of which passes through the cover. When charging, the cover is removed, the nitrate put in, the cover replaced, and the plug *c* drawn up; the process is repeated with the acid. The cover *a* can be luted with a little lime. 2°. Constant watchfulness also is requisite in respect of leakages from the leaden chambers, and in making necessary repairs. But the best constructed chambers will not last for ever, and the time at last arrives when they must be entirely renewed. 3°. The nuisance from the acid vapours proceeding from the evaporating vessel in which chamber acid is concentrated may be obviated by covering the vessel with a wooden or leaden cover, and causing the steam to pass either into a flue leading to the chimney of the works or into the vitriol chamber, or into some form of condensing arrangement. A compact and effective arrangement which I saw in use at Mr. Jackson's Chemical Works at Bradford, Manchester, is represented in the rough diagram Fig. 27. It consists of

FIG. 27.



a double series of 1-inch wide leaden pipes, *a* (38 in number), passing vertically between two horizontal leaden channels *b b*, into the uppermost of which the vapours to be condensed enter by the channel *c*. The whole apparatus is immersed in a tank *d*, containing cold water. The steam and acid which fail in being condensed here pass on to a leaden tower *e*, 14 feet high, and 2½ feet wide, packed with broken crockery, and supplied or not with water as requisite; from the top of this a discharge pipe leads to the chimney stack, the draught of which operates upon the whole apparatus back to the tank: *f f f* are pipes by which condensed liquids run off. A similar arrangement exists at Mr. Lowe's carbolic acid works at Reddish, but the exhausting agency there is a steam jet. I have already, p. 161, mentioned how the nuisance from concentrating is obviated at the Phœnix Aniline Works.

Where sulphuric acid is rectified in glass vessels, the manufacturer naturally for his own protection takes some pains to avoid the impingement of draughts of air upon his retorts. But this is not enough; he ought for the protection of his neighbours to do something to prevent annoyance to them when an accident happens. At Tennant's works in Manchester the rectification is carried on in a lofty chamber ventilated by a single opening above. When a breakage occurs the ventilator is

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closed immediately, and a flue, at other times closed, is opened, which flue is 16 inches square, and communicates directly with the tall chimney shaft of the works. But the most complete arrangements for rectifying in glass, that I have seen, is at Messrs. Chance's works at Oldbury. Against the inner wall of the house *a*, Plate XIX., is erected a glazed case or closet *b*, within which on successive stages *c*, each 1 foot lower than the preceding stage, are arranged the four retorts *d*, used in the continuous process of rectification. The retorts are heated by gas made on the premises, in the manner represented in Fig. 3, where the beak of the retort *e* is shown entering the leaden pipe *f*. The principle of the gas burner *g* is that of the ordinary Bunsen burner, the gas being supplied to each burner from the main pipe *h*. The special arrangement is shown in Fig. 4 in which a' is an $\frac{1}{2}$-inch gas pipe with an exit opening of $\frac{1}{5}$ in. diameter, and b' the pipe for conveying the mixture of gas and air, the air entering where shown by the arrow. The object of the glazed case is to protect the retorts from draughts, to keep warm the air surrounding the retorts, and to prevent any vapours which may fail to enter the leaden pipe *f* from being diffused generally in the room. For the ordinary ventilation of the closet there is a leaden pipe *i* provided, which passes from its upper part through the wall *a* to a leaden condenser *j*, packed loosely with coke; a pipe *k*, provided with a damper valve passes from the lower part of this to a flue leading to the chimney shaft. Any weak acid condensed here flows by a pipe *l* into a cistern *m*. In the event of one of the retorts breaking, the effused acid simply runs away by a pipe *n* into a cistern *o* provided underground, where it is all collected; and all that the workman has to do is to turn the gas off. Any acid vapours emitted are condensed in *j*.

Establishments visited.

THE MANUFACTURE OF SALT.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 3, 1879	Brunner and Mond	Winnington, Northwich.	Manufacture of carbonate of soda by the ammonia process. Lime burning.
„ 18, „	Jas. Lockey -	Ditto.	—
„ 19, „	Joseph Verdin and Sons.	Winsford, Cheshire.	—
„ 20, „	Worthington -	Witton, Northwich.	—
„ „ „	Milner - -	Marston, „	—
„ 24, „	J. Corbett, M.P. -	Stoke Prior Works, Worcestershire.	—
„ 25, „	Chapel Bridge Works.	Droitwich.	—
„ „ „	Coverscroft Works	Ditto.	—
„ „ „	Various other works	Ditto.	—

Brine.

This manufacture consists in the evaporisation of brine which has been raised from varying depths out of the earth by pumping. It is a trade pursued on the most extensive scale in certain localities in Cheshire and Worcestershire, the principal of which are Winsford and Northwich in Cheshire, and Droitwich and Stoke Prior in Worcestershire. In Winsford and its neighbourhood there are no fewer than 35 such works and a total of 606 pans, and in Northwich and its neighbourhood 30 such works with a total of 476 pans. In Droitwich there

are numerous works, but they are mostly on a comparatively small scale, with the exception of the Chapel Bridge and Coverscroft works, which belong to one company. The degree of concentration of the brine as pumped up varies both with locality and season; according to Mr. Verdin the brine used in Cheshire contains about 2 lbs. 10 ozs. of salt to each gallon. Mr. Otto Pohl found the average quantity of salt in the Winsford brine to be 26·25 to 26·50 per cent., receding in rainy weather, after a long drought, to 25 per cent. Beside common salt the brine contains a variety of other saline constituents, one of which is the chloride of magnesium: it contains, in addition, varying but small quantities of sulphates and carbonates of soda, potash, and lime, as also some alumina, silica, &c.

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Ordinary proces of manufacture of salt.

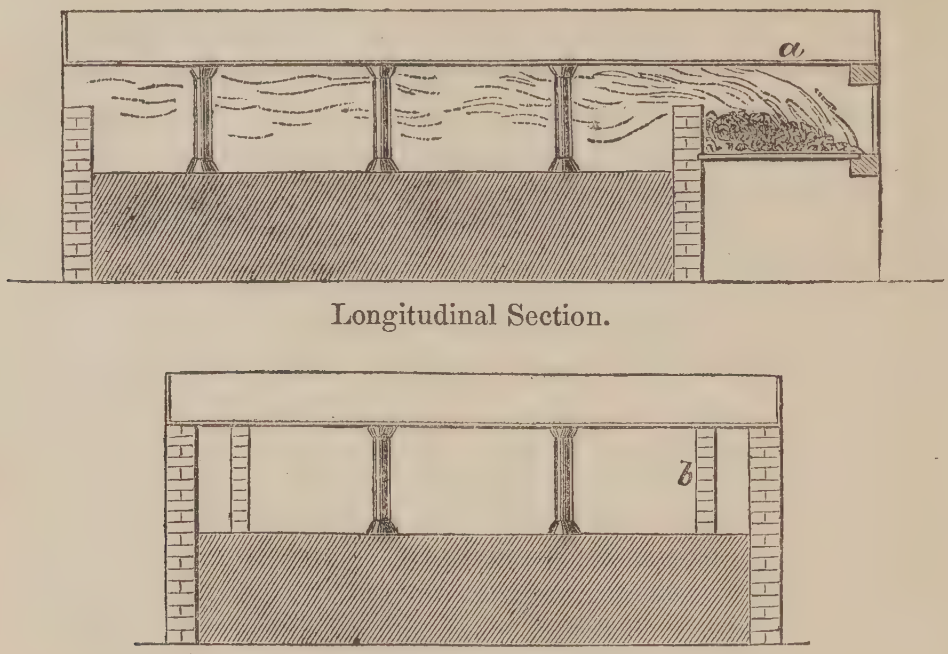
The pans.

The brine is first pumped into reservoirs, where it deposits any insoluble matter it may contain, &c., and from thence it is run off as it is required into the evaporating pans. The evaporating pans are sometimes open to the air, but mostly are placed within houses or sheds having ventilating openings in the roof by which the steam escapes. The size of the pans and their mode of heating vary, partly with the kind of salt required to be made and partly with the particular views upon the subject held by individual manufacturers. The kinds of salt made have reference to its intended use, and the difference in the various kinds lies rather in the size of the crystals than in anything else. Thus for table-salt the crystals must be fine; fishery-salt used for packing and curing herrings, &c. is coarse and large, while common salt used for alkali-making is intermediate between these two. The size of the crystals obtained depends upon the slowness or rapidity of the evaporation, and this again upon the amount of heat applied in the evaporation. The iron pans in which the evaporation is conducted are made of $\frac{1}{4}$-inch or $\frac{3}{8}$-inch boiler plates rivetted together, the sides are vertical and $\frac{1}{2}$ inch thick. The usual depth of a pan at the side is 1 foot 9 inches. The floor or bottom of the pan is made higher in the middle than at the sides, although, in consequence of warping, the reverse often comes to be the case. For fine salt a common size for a pan is 30 feet by 24 feet, that for "butter-salt" 40 feet by 24 feet, and that for common salt 60 feet by 24 feet; but sometimes pans are longer than this, it is not convenient to make them wider. At the Stoke Works and at works at Winsford there are pans for fishery-salt as much as 130 feet long. The pan is supported upon walls of brickwork at the sides and ends; but at the sides the pan usually overlaps a little the top of the supporting walls, so that there may be a part of the floor of the pan in this situation which shall not be exposed to heat so much as the rest of it. The pan is heated by either three and four fires placed under one end of it. In some works (and this is the ordinary plan adopted in Cheshire) 2 feet deep flues conduct the flame and heated air from each fire under the pan to a common flue at its further end; or a flue from each pair of the four fires passes to the end of the pan, when it turns back towards the fires, and on arriving at this end, back again to the further end of the pan. In other works (and this is the ordinary arrangement in Worcestershire) the whole space beneath the pan (with the exception mentioned) is open, the pan being supported by rows of iron pillars: in this case the whole space beneath the pan constitutes one large broad flue into which all the fires open, and from the further end of which the products of combustion are carried off by a brick flue.

Fig. 28 is a rough diagram illustrating this arrangement. The plates forming the floor of the pan are usually about 4 feet long by 2 feet wide, but it is customary to put very much smaller plates at the end of the pan at *a* which lies immediately over the fires. In the diagram the

dwarf wall *b* is represented as protecting about $1\frac{1}{2}$ feet of the sides of the pan from contact with the heated air.

Fig. 28.



Longitudinal Section.

Transverse Section.

Another kind of pan, a circular covered pan, is in use for making "butter" salt at the Stoke Works and at Messrs. Verdin's works.

Fig. 29.

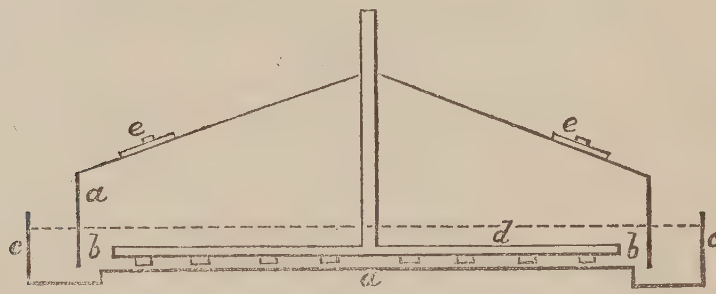


Fig. 29 is a rough diagram of this arrangement, showing the apparatus in section. The pan *a* is supported by iron pillars and is heated by fires beneath. At two places *b b*, on the circumference, the floor of the pan is open to a width of about 6 inches, and there are here troughs *c c* outside, into which the edges of the sides of the pan at the defective parts dip, the troughs being intended to receive the salt formed. The pan is provided with a four-armed scraper *d*, which is made to rotate and scrape the bottom by the arrangement represented. The steam from within the cover is conducted away to heat pans for making coarse or fishery-salt. The waste heat from the fires is similarly utilised. The dotted line represents the level of the brine in the pan and troughs; *e e* are man-holes fitted with appropriate covers. This is not the only instance of the utilisation of waste heat; the waste heat from ordinary fine-salt pans is commonly conducted by a flue through the room where blocks of salt are dried, either passing along the floor or being conducted beneath it.

Flues and chimneys.

The flues from the fires of the salt-pans usually terminate in a number of low chimneys, rarely higher than 40 or 60 feet, often not above 30 feet. The reason assigned for this practice of having numerous small chimneys, in place of carrying many flues into one tall chimney, is the

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danger likely to result to the latter from the subsidences of the land which occur commonly, and often to a very serious extent, in the places where large quantities of brine are being pumped up. I am disposed to believe that, although the practice is not without a reason, the fear it expresses is sometimes rather exaggerated. At Stoke Works there are several chimneys 80 to 100 feet high, and one chimney 312 feet high, which takes the smoke from seven large fishery pans as well as boiler smoke; and there are some tall chimneys at the Coverscroft Works at Droitwich. Mr. Milner writes to me that "there is very little danger "to tall chimneys from the sinking of the land; more chimneys fall," he says, "from waste brine getting to the base of them and there "swelling (by crystallisation?) until the chimney goes over." One chimney, say 80 feet high, to five large pans is, in his opinion, the most economical arrangement.

Evaporation of the brine.

The mode in which salt is made in the ordinary pans is as follows:— Brine is run into the pan until it is about three parts full: if a scum forms on the surface, it is removed by skimming; then salt forms on the surface and falls to the bottom of the pan, and, when it has accumulated sufficiently, is removed by means of a perforated scoop. The process of evaporation is continuous, brine being pumped in to fill up from time to time as may be requisite. A hard stony scale forms at the bottom of the pan to a thickness of from 1 inch to 2 inches or more, and has to be removed from time to time. In making "butter-salt," which is made quickly, a scale 6 or 8 inches thick will form in the course of a week.

Scaling.

The operation of scaling is ordinarily performed about once a week or once a fortnight. The fires are put out and the brine that the pan may contain is run off into drains, and workmen then enter the pan and break up and loosen the scale with a pickaxe and remove it with a shovel. At the Stoke Works scale is removed about every two days, before it becomes thick and while the brine is yet in the pan, by a man who stands and moves about in the pan with his feet in buckets. There are two kinds of "scale," known respectively as "pan-scale" or "scratch" and "salt-scale." "Pan-scale" is that which is removed from the common-salt pans where the brine is evaporated at about 180°. "Salt-scale" is that which is removed from pans in which the brine is evaporated by boiling at a temperature of 226°. The following are the results of an analysis, made for me by Mr. C. Tookey, of a specimen of each kind of scale from the works of Messrs. Gibson, of Anderton:—

—	Common salt. — Pan-scale or "scratch."	Butter pan. — Salt-scale.
Chloride of sodium	0·14	90·62
Sulphate of lime	83·00	8·02
Carbonate of lime	1·07	0·25
Peroxide of iron	Traces	Traces (with magnesia)
Water	15·65	0·90
	99·86	99·79

The scale is carried away to a heap or tip somewhere on or near the premises. At some works salt-scale is ground up to be sold for agricultural purposes.

Nuisances from salt works.

Salt works vary in the same way as other sorts of chemical works in respect of cleanliness and neatness. At some, such as the Stoke Works, care is taken that the waste and dirty salt is removed regularly from

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the platforms and floors about the pans, and that there shall be no sloppiness anywhere about the premises. At other works I have visited no care appears to be taken in these respects; brine appears to be allowed to run away almost anywhere, forming sloppy pools and runlets; and dirty salt lies about the platforms and beneath the sides of the pans, and indeed almost anywhere else.

Two kinds of nuisance proceed from salt works, namely, smoke and acid fumes. That which is most obvious is the smoke which proceeds in dense black volumes from the low chimneys, obscuring light and vision. Where the works lie in a deep valley, as for instance, on the sides of the River Weaver near Winsford, the smoke hangs about the neighbourhood so that it is impossible to see any distance beyond the works. The acid vapour is also sometimes disagreeably perceptible even at some distance from salt works. I have myself perceived it unpleasantly at a distance of more than a mile, and Dr. Roden, of Droitwich, tells me he has perceived it at a distance as great as 2 miles. I believe also that I have perceived the odour of free chlorine in the vicinity of salt works, and within a radius of 100 yards and more of them. It has appeared to me to come from the waste heaps, when ignited, but how it is produced (if it be chlorine) I cannot understand. The vegetation of the immediate neighbourhood is commonly destroyed much in the same way as by the acid fumes from alkali works, but not to anything like so great a distance around the works. These nuisances from smoke and acid are not invariably observed, nor even the injury to vegetation. I could perceive none of them outside the works at Stoke Prior.

1. Causes of smoke nuisance.

1. *As to the smoke nuisance.*—Various circumstances conduce to this. The material used is dusty fine coal commonly denominated "slack." That used in Cheshire is, I am informed, mainly derived from Wigan and other parts of Lancashire, but some of it comes from North Staffordshire. The coal used in the Worcestershire district is mainly from Leicestershire, South Staffordshire, and Cannock. The slack used is not previously washed, so that it necessarily contains more pyrites and shaly matter than washed slack would contain. Its cost is about the same both in Cheshire and Worcestershire, namely, from 5*s.* to 6*s.* 6*d.* per ton as laid down at the furnaces. According to Mr. Falk, that used in Cheshire is of the cheapest and worst description, and such as would otherwise have been wasted. The coal I saw in use at Stoke Prior and at the Coverscroft Works in Droitwich, where the amount of smoke was at the time of my visit very much less than I observed in Cheshire, was apparently of better quality, consisting of larger pieces, and being much less dusty than the slack which I saw generally in use in Cheshire. The mode of burning it in the fires is rough and clumsy. The slack is heaped in upon the fire-bars in a dense thick mass or hillock, through which it must be difficult for the air entering by the fire-bars to penetrate; and hence a great part of it can only be burned imperfectly with the production of a good deal of smoke. The quantity of slack used in Cheshire to produce one ton of salt is stated by Mr. Falk to be 12 to 12½ cwt. Mr. Brydon, the manager of the Stoke Prior Works in Worcestershire, which belong to Mr. Corbett, M.P. for Droitwich, and Mr. Bradley, of the Droitwich Salt Company, both assured me that the quantity that was used at these works was not less than 15 cwt. to 1 ton of salt. But the quantity of slack used at any works really depends upon the kind of salt which is made, more being expended in making one kind of salt than in making another kind. The usual expenditure of slack for the making of one ton of the different kinds of salt is, I am informed on good authority, as follows, viz.: for "common" salt, 9 cwts.; "butter"

salt, 12 cwts.; "fishery" salt, 10 cwts., and for some kinds 12 cwts.; "stove" salt, 15 cwts. Referring to only two districts in Cheshire, it appears from Mr. Falk's evidence given before the Noxious Vapours Commission, that in Winsford salt district, comprising only about 200 acres of land in the valley of the Weaver, no less than 500,000 tons of slack are thus consumed annually, while in the Northwich salt district, of about the same extent, 200,000 tons are annually consumed. It was admitted by Mr. Falk in his evidence that the combustion was very crude, and that a good deal of unconsumed fuel was carried off with clinkers to the tip. Another reason for the nuisance is the ordinary shortness of the flues and the small height of the chimneys from which the smoke is discharged. But there is another cause of the smoke nuisance, which indeed is believed by Mr. Milner to be the principal cause of it, namely, the alteration which occurs in the pan by reason of its irregular expansion under the influence of heat. When the fires are lighted the pan over them rises off its bed, and the result is that spaces are formed all round, through which cold air finds ready access and mingles with and cools down the gases proceeding from the fires to the extent of preventing their due combustion.

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2. Sources of acid fumes.

2. *As to acid fumes.*—These are partly discharged in combination with the smoke and ordinary products of combustion from the chimneys, and partly from waste heaps which have become ignited. *a.* The acidity of the watery vapour is due to the decomposition of chloride of magnesium, which readily decomposes when its solution is evaporated. But this alone would not create an offensive nuisance, the acidity of the vapour not being perceptible to the senses; but it contributes to the general acidity of the atmosphere in the salt districts. *b.* Mr. Falk, in his evidence before the Commission, attributed all the damage done to vegetation to the sulphurous acid produced by the combustion of the slack. This source of acidity would be unaffected by any improved combustion of coal. It has not, however, appeared to me that the offensive acidity perceived in the atmosphere has been due simply to this cause; the smoke from the chimneys is not for the most part decidedly acid to the senses. *c.* Acid vapours, which are discharged from the chimneys in such quantities as to be disagreeable, appear to result from the decomposition of salt which has gained access to the fires beneath the salt pans. In that case the acid evolved is hydrochloric acid. There are two ordinary causes of this accident: one, and the most important, is the leakage of brine from the pans into the fires and fire flues. I have stated that the pans are made of boiler plates rivetted together. After a pan has been in use for some time these plates become warped (in the parlance of the district they "buckle"), the rivets become loosened, and brine issues from between them, forming commonly beneath the pan hard stony stalactitic or stalagmitic masses or columns technically termed "salt-cats." Moderate issues of brine in this way attract no practical notice. From time to time it becomes necessary to patch the floor, but at last the floor becomes so irregular from the "buckling" it has undergone and the damage done by picking out the scale, that it has to be entirely replaced by a new one. The object of putting small plates in the part of the floor immediately over the fires is to obviate the tendency to "buckling" in this situation and the escape of brine directly into the fires. But, for all that, I have frequently noticed an abundance of salt deposited on the back and side walls of the ashpits, as well as brine lying in the ashpits themselves, showing that leakage had occurred even close to the fires. The other cause of the accident in question, in works which are conducted in a slovenly manner, is the admixture of brine or loose salt

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with the slack, which, for the convenience of the fireman, is placed in a heap on the ground at a short distance from the mouths of the fire-places. Under such circumstances salt may be unintentionally fed in with the slack. Chemically, the evolution of hydrochloric acid when salt or brine gains access to the fire or flues may take place two ways: One of these is the re-action which occurs when sulphurous acid with watery vapour and air come into relation with chloride of sodium,—a re-action which will be further explained when Hargreave's process for making "salt-cake" comes to be considered (p. 199), and the other is the action of the salt upon the silica of the bricks, of which the fire-places and flues are constructed, when they are at a red heat. That such action does take place is obvious on a very cursory inspection of the fire-places, the surfaces of the bricks of which are always found to be highly glazed. They have in fact the same appearance as the bricks on the inside of a salt-glaze pottery kiln. *d.* The "tips" or heaps of waste may be a source of acid emanations. These heaps, which are often of large size, consist of clinkers and cinders from the fire-places mixed with portions of pan-scale or salt-cat, and perhaps also with salt or brine which may have oozed or flowed into the ashpits. I have heard it said that they ignite spontaneously; it would be more correct, I think, to say that they become ignited accidentally. Probably the most common mode in which they take fire is from cinders thrown upon them while in an ignited state. The vapours proceeding from one of these heaps when on fire are strongly acid and pungent, having, in addition, an odour in some degree resembling that from a London brick-kiln, and sometimes an odour as if they contained free chlorine. There can be no doubt that when such an accident as this occurs the nuisance occasioned to the immediate neighbourhood is much greater than from any other source. At the spots upon the burning heap at which the offensive vapour issues a crystalline efflorescence is observable, which consists essentially of chloride of ammonium, sometimes mixed with yellow perchloride of iron.

Influence upon health.

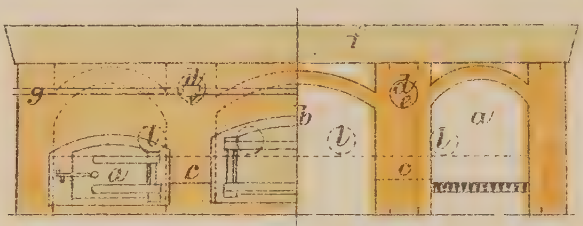
Except in the case of the vapours from waste heaps, I have no direct evidence of evil effects upon health in the salt districts from the smoke and acid fumes thrown into the atmosphere. Their unwholesomeness can only be a matter of inference on general principles. But in the case of the waste heaps I have satisfied myself by inquiry that the vapours, when sufficiently abundant and in a sufficient state of concentration, are irritating to the eyes and organs of respiration at a distance of at least 80 yards, and that they may occasion a sensation of suffocation or oppression at the chest and cough, with general malaise, headache, and loss of appetite. Dr. Roden, of Droitwich, informs me that they are particularly distressing to persons who are labouring under any pulmonary affection.

Prevention of nuisance.

There appears to be no chemical manufacture on which tradition has obtained a more powerful hold than that of salt. Except so far as the size of the pans is concerned, the process is said to be precisely the same as it was when brine was first evaporated by artificial heat in this country; and, judging from the general tenour of the evidence given to the Noxious Vapours Commission by Mr. Falk, the President of the Association of the Salt Chamber of Commerce in Cheshire, he is hopeless of improvements being materially effective, or of improvements that have been suggested of late years being at all likely to secure anything like general adoption. Pessimist opinions are always easy to express, but not always very easy immediately to refute: it may, however, be said that this is not the first trade in which they have been as strongly expressed, but in the end refuted by the results of subsequent expe-

J. T. LOCKEYS EVAPORATING PAN. FOR BRINE.

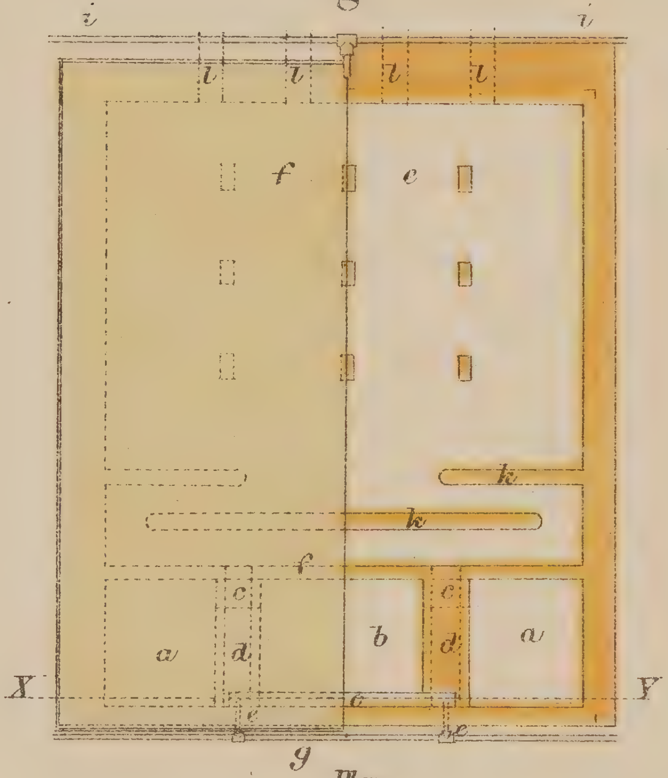
Fig 1.



Elevation

Vertical Section through X.Y.

Fig 2.



Plan

Dangerfield. Lith. 22. Bedford St. Covent Garden

rience. I shall therefore proceed to point out some directions in which attempts at improvement are being made, where it appears to me that such improvements are likely to result in the lessening of nuisance; and to make such other suggestions as arise out of my experience in other trades.

1. As to smoke nuisance.

1. *As to the smoke nuisance.*—Mr. Falk admitted in his evidence (7667) that it was practicable so to burn the coal as to avoid the emission of dense black smoke for any length of time, and that the emission of such smoke can be readily kept within moderate limits by the exercise of a little care. I have further the fact told me by Mr. Neumann, the Chairman of the Local Board of Northwich, that, prior to the last three years, when an active inspector was employed to attend to the smoke nuisance, there was very much less of it than there has been since the inspector has been employed in other kinds of work, and has been compelled to give less of his time to the prevention of this particular nuisance. Mr. Falk says that the difficulty of getting improvements in the furnaces into use at salt works lies with the firemen, who either cannot or will not adapt themselves to changes. I am quite aware of this kind of difficulty; it has had to be combatted in other trades besides salt making, and over and over again it has been overcome by the determination of the masters; and I see no reason why a similar mode of meeting it should not be equally successful in this case. The first suggestion I have to make refers to the mode of firing. It is difficult to believe that this is incapable of improvement. Mr. Falk admits (7732) that he has not the least doubt that a better system of stoking would result in less black smoke being sent into the air and also in a saving of cost for fuel. In the second place, I may observe that Mr. Verdin considers that at his works a diminution of black smoke has been obtained by a trifling improvement made in his furnaces, which he has widened somewhat so as to obtain more grate space and admit a greater amount of air to the fire. Thirdly, an advantage would undoubtedly be obtained by sufficiently lengthening the fire-flues and discharging the smoke from one or more tall chimney shafts instead of from a large number of low chimneys. With respect to the influence of a long flue, I observed at the Coverscroft Works that when I caused the fires of the fine-salt pans, the flue from which passed through a drying room to the chimney shaft, to be stoked in the ordinary way, very little smoke issued from the chimney shaft; whereas smoke issued in considerable quantity from another chimney which, without the intervention of a long flue, received the smoke from the fires of the pans where coarser salt was made. The long flue referred to made a circuit on the floor of the drying room so as to attain a total length of 180 feet. The result was the same at other works in Droitwich; there was always less smoke from the chimneys attached to the drying rooms than from other chimneys. Fourthly, as respects the entrance of cold air between the pan and its bed, there appears to be no method by which the rise of the pan from its bed can be prevented. There are no known means of holding the pan down.

Mr. Lockey's method of lessening smoke.

I have now to draw attention to a patent arrangement by which smoke is said to be lessened, adopted at Winnington by Mr. James Lockey. Plate XXII. illustrates this method. It consists essentially in the use of a jet of steam to increase the draught of the furnace (which is not novel), and of an oven or kiln (which Mr. Lockey uses for burning lime), interposed between the furnace and the space beneath the pan. In the drawing, *a a* are ordinary furnaces, separated by party walls from the oven *b*; the heated air and flame pass from near the top of *a* to *b* by means of a flue *c* at the back of the furnace; *d d* are brick flues open at

one end to the space *e* beneath the pan *f*, and at the other end to the oven or kiln *b*; *g* is a steam pipe having nozzles concentric with each of the flues *d d*, so as to cause a strong draught through the flues by means of a small jet of steam; *h h* are the stages for draining the salt crystals raked out of the pan; *i* the brine pipe for supplying the pan with brine. The pan *f* extends over the furnaces, but to shield it from the direct radiant heat which would prove injurious to it, Mr. Lockey arches over the furnaces and kiln, leaving only a slit *o*, a few inches wide, close to the front wall of the oven. Mr. Lockey says that the tendency of the steam jet is to drive the gases at once straight through the centre of the space beneath the pan, leaving almost stagnant air on each side; to obviate this he makes a split draught and causes the heated air to take a circuitous course by means of brick partitions *k k*.

I did not myself see this arrangement actually working, but Dr. B. W. Richardson stated in his evidence to the Commission (7484) that he was present when the furnaces were charged with fuel, and that the smoke from the chimney, the escape from which at the most was very slight, was rendered all but invisible in seven minutes.

Mr. Milner's method of salt making.

At Mr. Milner's works, at Marston, an experiment is now in progress for making common salt for the alkali manufacturers by passing the flame from a furnace of peculiar arrangement over the surface of the brine in the pan, instead of beneath the pan. The pan, of course, is covered, and the arrangement is essentially that of a reverberatory furnace. One advantage obtained is a notable diminution of the smoke, chiefly in consequence of good arrangements for the combustion of the fuel, and partly in consequence of the deposition of part of the fuliginous matter upon the surface of the brine, whence it falls with the salt to the bottom of the pan. Time only will show whether this process when perfected can be economically conducted.

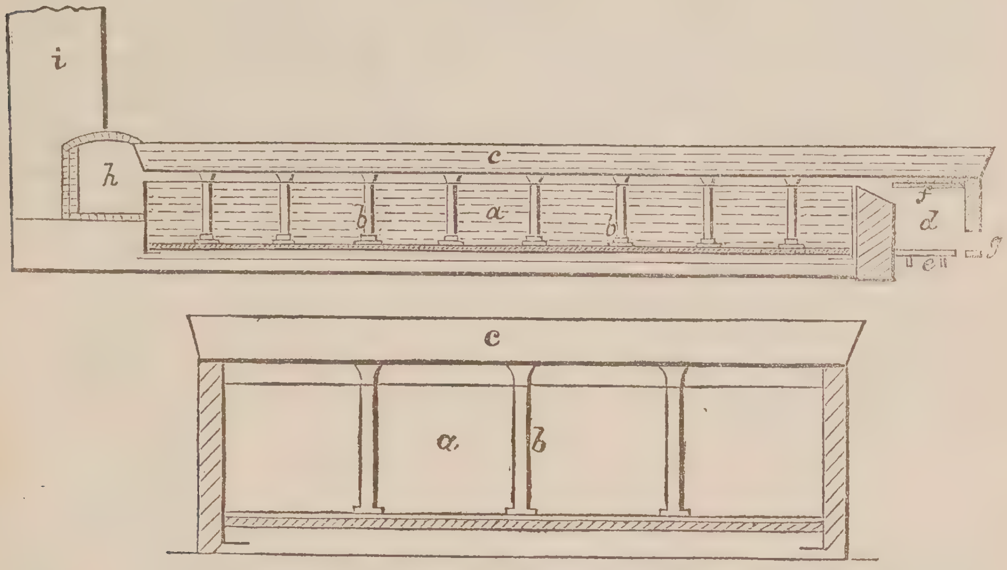
Mr. Pohl's method of salt making.

Mr. Milner pointed out to me that the principle of his arrangement was not new, and kindly put me into communication with Mr. Otto Pohl, who has for some few years past been experimenting upon the subject at his own works. Mr. Pohl has expressed his views, and given the results of his working in a pamphlet which is well worthy of being studied.* Experiments, which he details, satisfied him that there was a great loss of heat as well as great waste of fuel in the traditional mode of salt-making, and that the loss of heat was most remarkable in the boiling process for making "butter-salt." Testing the temperature of the gases leaving the chimneys, he found that from common salt pans the temperature of the chimney gases was 600° Fahr. and upwards; and finding that the chimney gases from butter salt pans melted zinc and made iron red hot, he concluded that they must have been of the temperature of 800° or 1000°, the highest temperature being observed when the pans required scaling. Referring this loss of heat and consequent waste of fuel to several causes, viz., the irregular and unsystematic way in which the fire-bars are commonly arranged, the neglect of adapting the furnace arrangements to the kind of coal used, or *vice versâ*, the very faulty but traditional mode of stoking which I have described above, the impediments to the draught occasioned by the accumulation of soot in the flues and upon the bottom of the pan, and the choking of the flues in this way and with "salt-cats," and the disturbances of the proper disposition of the pans by "buckling," and dilapidations of their brick supports, &c., he determined to try what could be done by applying the heat to the surface of the brine instead of

* "How to make three tons of salt instead of two tons with the same quantity of fuel and less labour."—By Otto Pohl, Salt Merchant, Liverpool, 1878.

to the bottom of the pan, with due arrangements for full combustion of the fuel. The following diagram, Fig. 30, illustrates the arrangement of pans he adopted:—

Fig. 30.



a is a pan of the ordinary length and width, and 6 feet deep, and above it (supported upon iron pillars *b* rising from the bottom of the pan) is another shallower pan *c*. The interval between the pans is $4\frac{1}{2}$ inches. The sides of this interval are closed in, so that a flue varying in depth with the quantity of brine in the lower pan is formed by the brine below, and the bottom of the upper pan above. The fire place or furnace is represented at *d*, and was found to answer best with a height of $6\frac{1}{2}$ feet from the fire-grate *e* to the arch of the furnace *f*. The fire door is at *g*, and *h* represents the smoke box, and *i* the chimney. There is an arrangement for firing in small charges of about 50 lbs. each of slack. The stoking is performed by shoving the caked fuel back, and throwing the new charge on the emptied space in front. The following were the results of 16 days working, during which the temperatures of the pans were taken every 12 hours in different places. The average in the top pan was, near the fires 160°, in the middle 150°, and at the end 120° Fahr. The temperature in the bottom pan must have been constant at 226° Fahr. on the surface of the brine, since only the finest "butter-salt" was found in it. With the strongest firing the temperature at *h* could not be brought beyond 288° Fahr. No black smoke, Mr. Pohl says, left the chimney, though a quantity of soot was found in *h*, and some in the salt. The former he regarded as due to the soot deposited first on the surface of the brine, and, being flakey, not becoming wetted, but being blown into the smoke box by the draught; and the latter to the soot caked upon the bottom of the top pan being detached by the blows of the rake in the removal of coarse salt from the top pan, and falling into the brine below, where it became mixed with the deposited salt. The "butter-salt" formed contains from 2 to 3 per cent. of sulphate of soda, due to the reaction between the sulphurous acid from the combustion of the coal, the steam, and the salt; and the salt thus contaminated is increased, he says, in value for salt cake making. As respects the expenditure of fuel, Mr. Pohl gives the following as the result of the 16 days boiling of brine (containing on an average 25·27 per cent. of salt) with 57 tons of slack from Little Houlton, in Lancashire, viz., 82 tons of fine butter salt, and 49 tons of common (coarser) salt. He says that on the old process the 82 tons of butter salt would have taken to make them 54 tons 13 cwt. of slack, and the 49 tons of

coarser salt 26 tons 10 cwt., or a total of 81 tons 3 cwt. He consumed at this working 57 tons, giving on that calculation a saving of 24 tons 3 cwt.* From the point of view of this report, the advantage of Mr. Pohl's process lies in the prevention of black smoke; but there must be some discharge of hydrochloric acid from the chimney, proportionate to the quantity of sulphate of soda formed, and to the quantity of sulphur acid in the products of combustion of the fuel arrested in forming it. Mr. Pohl says that some caking of the nature of scale occurs around the supporting pillars *b*. Mr. Milner has found some such scaling occur in his pans. Mr. C. Tookey analysed the scale for me, and found it composed as follows:—

Sulphate of lime	62·90
,, soda	7·04
Chloride of sodium	26·66
Water	3·50
Peroxide of iron	traces
	100·10

Some little additional hydrochloric acid then must escape equivalent to the sulphate of soda formed here. But Mr. Pohl says that he has an almost entire absence of pan scale formation in his top pan, and is therefore saved from the dilapidations produced by the process of its removal.

As to acid fumes from chimney.

2. *As to the evolution of acid fumes with the chimney smoke.*—The sulphurous acid given off from the combustion of the coal would unquestionably be less were a less sulphurous coal substituted for the kind of slack commonly used. But, even with the slack used in Cheshire, there is no doubt that advantage would be gained by the purchase of slack that had been previously washed, a process which it is believed would add the merest trifle to its cost. From observations recorded by Dr. Angus Smith (Air v. Rain, p. 446), it appears that the presence of salt diminishes the quantity of sulphurous acid given off in the combustion of coal, causing the retention of the sulphur in the ashes. The leakages of the pans, therefore, may probably be regarded as so far lessening one source of acidity in the smoke, but they merely substitute another for it. So long as open evaporation shall be used, the only expedient for lessening the tendency of the floor of the pan to "buckle," that experience seems to justify, is the adoption of small plates, now used only at the fire end, over the whole of the floor, instead of large plates. This would add considerably to the cost of the pans; but probably the pans would last longer and require fewer repairs than they do now. It is a matter that only experiment can decide, but it appears to me desirable that a trial should be made.

Mr. Lockey's new salt-making machine.

But Mr. Lockey, of the Phœnix Works at Winnington, proposes to do away with the use of open pans for making all but coarse salt, and altogether with the use of fires beneath pans for making coarse salt. If he should succeed practically and economically, and can show a decided economy in his process, there will be an end of the necessity for the occasional occurrence of nuisance from leakage. He has patented his process, which may be seen at work on a small or experimental scale at the Phœnix Works. Plate XXIII., the drawings for which werefurnished to me by Mr. Lockey, illustrates the apparatus he uses. It consists of a

* On the scale of expenditure of fuel given at p. 186, the 82 tons of butter salt would have required on the old method only 49 tons 4 cwts. of slack, and the 49 tons of common salt 22 tons 1 cwt. of slack, so that probably Mr. Pohl's estimate of his saving may be too high.

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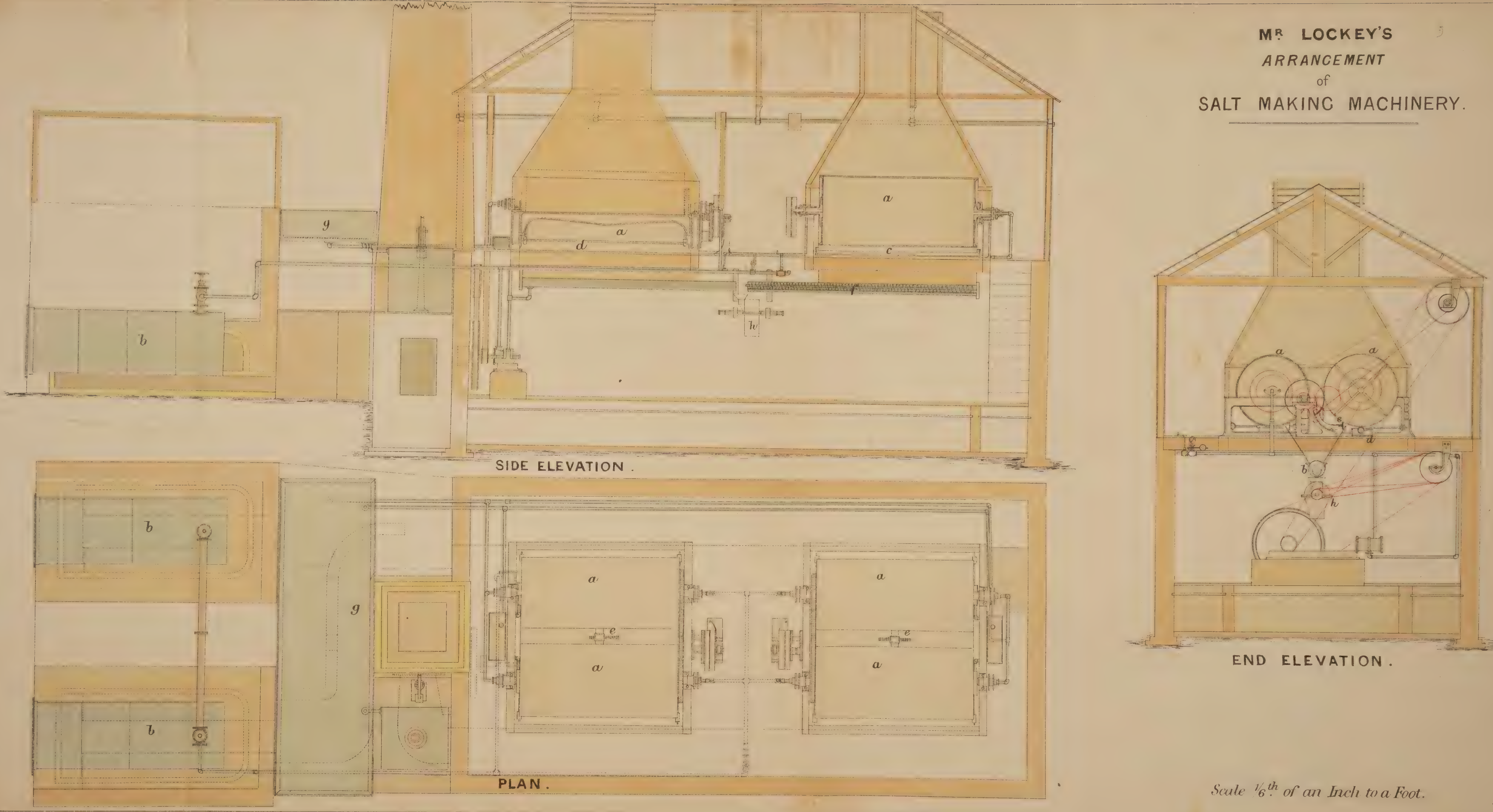

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pair of iron or steel hollow cylinders *a*, which revolve in opposite directions on their axes, and are heated by steam at 220° Fahr. from an ordinary steam boiler *b*. Beneath each cylinder there is a small roller *c* covered with india-rubber, which revolves in a trough *d* filled with brine and in contact with the heated cylinder. The brine is by this means laid on the heated cylinders in a thin film, and the rate of revolution of the cylinders is so regulated as that the necessary time for the evaporation of the water is afforded. The salt left by the evaporation adheres to the cylinders, and is scraped off, when sufficiently dry, by a knife or scraper *e*, which is made to travel from one end of the cylinder to the other slowly, and thus to scrape the salt off all parts of the cylinder in succession. The salt falls into a trough *f* containing an endless screw, which conducts it to a disintegrator *h*. The waste heat from the cylinders is conducted away through a pipe and is used to heat brine contained in a tank *g* to 170° or 190° Fahr., and for making there other coarser kinds of salt. The hot water from the condensed steam is pumped back for the supply of the boiler. Mr. Lockey claims, among other advantages from his patent, economy of fuel, stating that 40 per cent. more salt can be made from a ton of fuel than on the present system, economy of space, greater speed in production, less necessity for repairs, the avoidance of leaky pans and of waste of brine, and great diminution of the smoke nuisance. Whether all or most of these objects will be realised experience only can determine. Meanwhile the ingenuity and courage of Mr. Lockey in thus attempting to revolutionise salt manufacture are commendable. The cylinders I saw in use at his experimental works were each 4 ft. long and 2 ft. 4 in. wide, and they made nine revolutions in a minute. He is, I understand, now erecting cylinders on a larger scale.

3. As to waste heap nuisance.

3. *As to the waste heap nuisance.*—So far as Winsford and Northwich are concerned, this nuisance ought never to occur even by accident, since it is quite unnecessary there that waste heaps should be formed at all. In the neighbourhood of both these large centres of salt making, the land has in several places subsided to such an extent as to form deep hollows or depressions, now filled with water, which are locally known as "flashes." The subsidence is still progressing, and fresh landslips occur from time to time, and as they occur they become filled with water. These flashes are the natural depositories of salt-makers' refuse, whether it be furnace refuse or scale, and by some of the manufacturers are habitually so used, and have been so used for many years without producing any permanent diminution in the depth of water. Probably, although I cannot be expected to know of them, there are other salt-making districts similarly circumstanced; and where this is the case there could be no hardship in requiring manufacturers to use these depressions for the disposal of their refuse. But even when a heap must needs be formed somewhere, care ought to be taken that it is not fired even by accident; and the fact that such heaps are usually ignited by the deposition of hot ashes upon them points to the precaution to be adopted. Each addition of hot ashes to the heap should be spread in a thin layer upon it with a rake, when it will quickly cool. When a heap has once become thoroughly ignited it is no easy matter to extinguish the fire. The best mode appears to be to cut a trench through the heap down into the earth beneath, so as to cut off the ignited from the non-ignited portion, and then either to allow the ignited part to burn itself out, or to dig it down and extinguish it in detail with water. It is of little or no use to cause water to flow upon the heap; for, instead of soaking in and extinguishing the fire, it is apt to form for itself channels over the surface, by which it runs off, the nuisance from the acid vapours being rather increased than lessened by the procedure. An accidental fire should be extinguished immediately it is

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discovered, and before it has had time to spread. So long as it is superficial, this can be done by means of water. Of course brine should not be used for this purpose, since its employment would result in a large and noxious evolution of hydrochloric acid. Mr. Verdin is of opinion that the greatest mischief produced by the cinder heaps arises in this way, brine being the nearest thing at hand to extinguish an accidental fire with.

THE MANUFACTURE OF ALKALI.—RECOVERY OF SULPHUR FROM THE TANK WASTE.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Jan. 18, 1876 -	Thomas & Co. -	Bristol - -	Manufacture of soap, composite candles, &c. Recovery of sulphur from waste.
20, ,, -	Netham Chemical Works.	Ditto -	Manufacture of bleaching powder and artificial manures. Recovery of sulphur from waste.
Feb. 2, ,, -	Roberts, Dale, & Co.	Warrington -	Manufacture of oxalic acid and size.
,, 21, ,, -	Crossfield -	Ditto -	Manufacture of soap.
,, 24, ,, -	Squire & Co. -	Victoria Docks	Manufacture of bleaching powder and sulphuric acid.
,, 29, ,, -	Gerard's Bridge Chemical Works (Gamble and Son).	St. Helens, Lancashire.	Ditto.
,, ,, ,, -	Hardshaw Brook Chemical Works.	St. Helens, Lancashire.	Ditto.
,, ,, ,, -	Bridgewater Chemical Works.	Ditto -	Ditto.
May 16, ,, -	Howarth - -	Manchester -	Manufacture of sulphuric acid.
,, 18, ,, -	Sullivan & Co. -	Widnes -	Manufacture of sulphuric acid and bleaching powder.
,, ,, ,, -	Gaskell, Deacon, & Co.	Ditto -	Ditto.
,, ,, ,, -	Atlas Chemical Works.	Ditto -	Ditto.
Dec. 5, ,, -	St. Rollox Chemical Works.	Glasgow -	Manufacture of sulphuric acid and bleaching powder. Recovery of sulphur from waste.
,, 6, ,, -	Charles Tennant & Co.	Hebburn -	Manufacture of sulphuric acid and bleaching powder.
Mar. 22, 1877 -	Tyne Alkali Works.	South Shields -	Manufacture of sulphuric acid and bleaching powder, and chlorate of potash.
,, 23, ,, -	Jarrow Chemical Works.	Jarrow - -	Manufacture of sulphuric acid.
,, ,, ,, -	Richardson -	Ditto -	Manufacture of sulphuric acid and bleaching powder.
May 14, ,, -	Slack, Ashcroft, & Co.	Pump Fields Liverpool.	—

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 14, 1877 -	James Muspratt and Sons.	Vauxhall Road, Liverpool.	Manufacture of sulphuric acid and chlorate of potash.
„ 15, „ -	Ditto - -	Widnes -	Manufacture of sulphuric acid and bleaching powder. Recovery of sulphur from waste.
„ „ „ -	Golding, Davis, & Co.	Ditto -	Manufacture of sulphuric acid and bleaching powder.
Mar. 14, 1878 -	Richard Bealey & Co.	Radcliffe, Manchester.	Manufacture of sulphuric acid and bleaching powder and liquor. Bleaching.
April 3, „ -	C. J. Schofield -	Clayton, Manchester.	Manufacture of sulphuric acid and bleaching liquor.
„ 4, „ -	Roberts, Dale, & Co.	Warrington -	(2nd visit.) Manufacture of sulphuric acid.
May 24, „ -	William Jones -	Middlesborough	Manufacture of sulphuric, acid and oxalic acid.
Jan. 24, 1879 -	Chance Brothers	Oldbury -	Manufacture of sulphuric acid and sal ammoniac. &c.
Feb. 20, „ -	Tennant & Co. -	Manchester -	Manufacture of sulphuric acid, nitrate of copper, chloride of tin, &c.
April 2, „ -	Hunt Brothers -	Castleford -	Manufacture of sulphuric acid and bleaching powder.
May 15, „ -	Muspratt Brothers and Huntley.	Flint - -	Ditto and reduction of copper by wet process.
July 10, „ -	St. Rollox Chemical Works.	Glasgow -	(Second visit.)

The manufacture of alkali from salt is one of the largest and most important of the chemical industries of the country. I need not add that the injury done to property by the fumes from works where this industry is carried on was, several years ago, such as to give rise to special legislation with regard to them, nor that there have resulted from that legislation very many and great improvements in the mode of working. In addition, there has resulted a series of reports from the pen of Dr. Angus Smith, the Chief Inspector under the Alkali Acts, which are most valuable contributions to chemical science, and constitute an unique body of literature relating to this particular trade. The first report under the Alkali Acts was made in the year 1864, and the subsequent annual reports have chronicled not merely the results of the inspections made, but every advance that has been made in perfecting the process.

It might therefore be regarded as a presumption on my part to write a single word on this subject. My experience of the manufacture is as nothing when compared with that of Dr. Angus Smith and his able coadjutors. For a long time I have hesitated as to what I should do in this matter, and have questioned whether after all it would not be more graceful and befitting that I should abstain from writing anything on the subject, and simply refer the Board to the reports already in their hands. But then I considered that, by adopting this course, I should be not only evading a duty laid upon me which I was bound, however imperfectly, to perform to the best of my ability, but that I should also be leaving my own report fairly open to the criticism that I had omitted the consideration of the very trade which has occasioned, perhaps, the loudest outcry.

I further considered that my point of view was not precisely that of Dr. Angus Smith, whose strictly official vision was circumscribed by the terms of the statutes under which he acts, although it must be at once obvious in his case that it was impossible that his vision should be thus restricted. And in addition, it occurred to me that some advantage to non-technical persons might be gained by an attempt to summarise, in such a general account of offensive trades as I am giving, some of the most important of the observations recorded in Dr. A. Smith's reports which have reference to the question of nuisance as distinguished from that of injury to property. I think it will appear in the sequel that this is a real distinction, which gives some warrantry for my dealing wth the subject, and for touching lightly upon several matters which Dr. A. Smith discusses very fully, as he was officially bound to do, and for dwelling longer on matters which he has touched comparatively lightly.

Process of manufacture.

I will first state briefly the main steps in the ordinary manufacture of alkali. The materials used are common salt, sulphuric acid, limestone, and coal. The salt is decomposed with the aid of heat by mixing it with sulphuric acid, which forms with it sulphate of soda, while hydrochloric acid is given off in the gaseous form. The resultant salt, sulphate of soda, is technically termed "salt cake." This salt cake is then mixed up with crushed limestone or chalk and coal, and again heated. The hydrocarbonaceous elements of the coal by taking oxygen from the sulphate reduce it to a sulphide of sodium, and then a double decomposition with the carbonate of lime of the limestone takes place with the formation of carbonate of soda and sulphide of calcium. Regarding for the moment the coal used as merely carbon, the following equations represent the decompositions :—

$$\text{Na Cl and HO, SO}_3 = \text{Na O, SO}_3 \text{ and H Cl.}$$
$$\text{Na O, SO}_3 \text{ and 2 C and Ca O, CO}_2 = \text{Na O, CO}_2 \text{ and Ca S and 2 CO}_2.$$

The mixed material which results from the last process is technically termed "black ash" from its colour. It is lixiviated with water which dissolves out the carbonate of soda, and when this solution is drained off the residue is known as "tank-waste."

In the ordinary rough working of alkali manufacture the results are necessarily not so neat and clean as are represented in the above description. For example, in the first decomposition the only vapour that is represented as coming off is hydrochloric acid, but in fact not only does this acid come off, but some sulphurous acid also may come off, as will be explained presently, and also watery vapour in consequence of the sulphuric acid not being used in the monohydrated condition, but in a less concentrated state. Again, in the second decomposition, where carbonate of soda, sulphide of calcium, and carbonic acid are alone represented as formed, there will also be watery vapour given off from the oxygenation of the hydrogen of the coal; and beside the two salts mentioned there will be in the black ash more or less carbonaceous or hydrocarbonaceous matter and limestone left unaffected, and also some of the original sulphate left undecomposed; and the exact chemical composition of the black ash, and consequently of the tank waste (if fairly sampled), will vary accordingly. The perfection of the decomposition, that is to say, the nearness of its approach to the theoretical result, will vary thus with the care used in selecting, apportioning, and preparing the materials used, and with the skill and experience of the workman.

Making the salt cake.

1. *Making the Salt Cake.*—This, although a single and simple decomposition, cannot in the usual mode of manufacture be effected in one process. There are two steps in the process, viz., *a.* decomposing, and *b.* roasting, and these two steps are performed in different parts of

SALT-CAKE DECOMPOSING PAN AND ROASTERS.

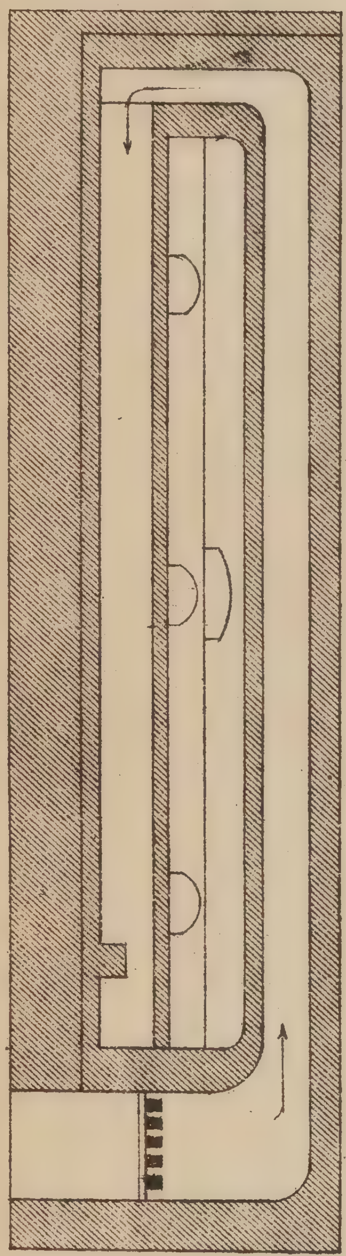

Fig. 2.

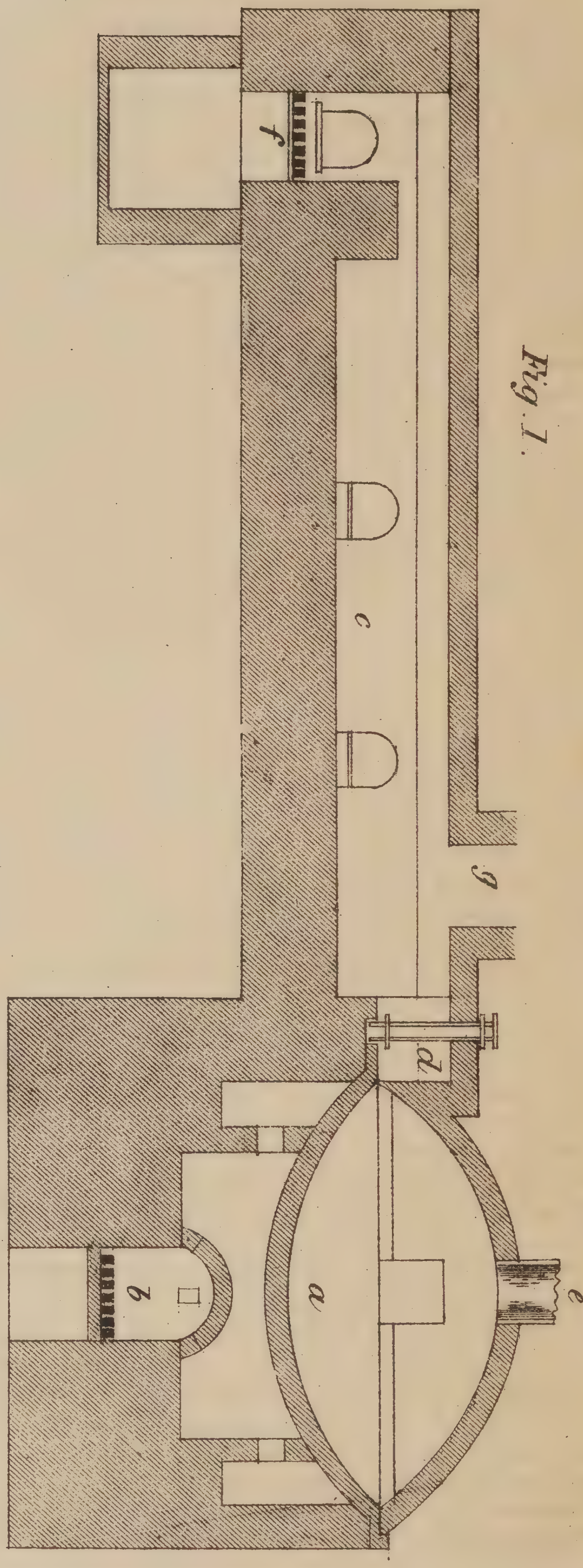

Fig. 1.

Dangerfield. Lith. 22. Bedford St. Covent Garden

the apparatus, viz., "the decomposing pan" and the "roaster" or "roasting furnace."

The decomposing pan may be connected with an "open" or "closed roaster," that is to say, it may be so arranged as that the flame and heated air from the fire may pass over the contents of the roaster, or so that the flame and heated air may not pass over the contents, but around the pan and roaster. Plate XXIV., Fig. 1, shows one form of what is termed the "open dryer;" *a* is the decomposing pan heated below by the fire *b*, which is shut off from the open dryer *c* by means of a damper *d*. The fumes from the decomposing pan pass off by the pipe *e*. The "dryer" or "roaster" is heated by a separate fire *f*, the flame from which passes over the material which is being roasted; the fumes with the products of combustion pass off together by *g*. In another form of open dryer the fumes and products of combustion from the roaster are allowed to pass over the contents of the decomposing pan and to escape by the same flue that carries off the fumes from that part of the apparatus. The decomposing pan is made circular in shape and of thick iron, is set in brickwork, and is generally heated by a separate fire beneath. The mode in which the decomposing pan is set in the brickwork is a matter of much importance, and Figs. 1–7 in Dr. Smith's 4th Report, p. 48, represent various modes of setting. Fig. 2 represents a "close roaster" or muffle furnace where the flame and products of combustion do not come into contact with its contents, but are carried first above the muffle and then back through a series of flues beneath it to the chimney. The following description of the process is that given in a recent work on Technical Chemistry*:—"Supposing the pan has just been heated up, " or else the previous charge has just been 'shoved,' the salt belonging " to the new charge is shovelled in as quickly as possible through the " charging door; and when about half of it is in, the acid syphon is let " down, so that the sulphuric acid begins to run in as well. The " quantity of salt for one charge varies very much. In working with " open dryers it is almost universally the custom to work one batch " each hour; these batches varying from 6 cwts. of salt up to 10 cwts. " With close roasters the charges are mostly larger, being from 12 to " 15 or even 18 cwts. of salt; but then only from 8 to 12 batches are " made in 24 hours. In any case the quantity of sulphuric acid must " be exactly measured, though the bulk of acid for a certain quantity " of salt will, of course, vary very much according to the strength of " the acid and to its temperature. As far as the strength is concerned, " the stronger the acid is the better, up to 144° Tw.—a strength which " is frequently reached at the present time when Glover's towers allow " of the concentration of all the acid made in most alkali works. On " the other hand, where there is no convenience for concentrating the " acid, it is sometimes used as low as 120° Tw.; but the weaker the " acid, the more time and coal does it take to do the work, the more " difficult is the condensation, owing to the large amount of steam, and " the more quickly are the pans worn out. . . . If the acid comes " hot enough from the towers or pans, it is not necessary to heat it in " the guage cistern; but if cold, the latter ought to be heated so that " the temperature of the acid may at least reach 120° Fahr., otherwise " it cools the pan (which is already greatly cooled by the salt) far too " much, and may even cause it to crack. The absolute quantity of acid " to be used depends very much upon the quality of the sulphate

* "Chemistry: Theoretical, Practical, and Analytical, as applied to the Arts and Manufactures." Mackenzie, Glasgow, 1879. Edited by C. W. Vincent, F.R.S.E., Royal Institution, London.

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" desired ; if strong sulphate has to be made, as is usual in open dryers, " the proportion of acid of 144° Tw. to Cheshire salt of average " moisture will be about 95 : 100. . . . When all the acid has been " run in, and all the salt is charged, the whole is well mixed by means " of a light iron rake. At this stage the mass is very liable to froth " and even to boil over, which very soon destroys the pan arch ; and it " is therefore usual to throw a few ounces of tallow or other grease into " the pan, in order to keep down the froth. The door is then put on " and made tight with salt, but the rake is left in and occasionally " worked about ; the salt serving as a kind of stuffing box for the gas. " After about half an hour the salt will be dissolved in the acid (for " large batches it takes more time). . . . . After the salt is all " dissolved the fire is urged more strongly, in order to 'boil down' the " batch, and this is continued until the mass becomes so stiff that the " workman feels considerable resistance to the working of the rake in " it. He then slackens the fire, pulls up the damper, and removes his " charge into the furnace, which by that time must have been emptied " of its own charge. The removal is effected, in case of 'shoving,' by " means of an iron rake whose head is bent in a slight curve, and " follows the sweep of the pan ; in case of 'casting' by means of a " large and slightly hollowed shovel with an iron handle. . . . . In " the furnace the batch is at once spread out in an even, thin layer, and " exposed to the heat of the fire. During the operation it is several " times turned over by means of a paddle . . . the lumps are crushed " down, and the whole is now and then raked through with a tooth-" rake. Great care is requisite to mix up all parts of the batch, " otherwise there will be portions of it very poor, that is, containing " undecomposed sodium chloride ; and others over strong, containing " sodium bisulphate. It is evident that this careful working is very " much easier in a reverberatory furnace, both because it is lighted up " by the fire, and because the heat is so much greater than in a muffle " furnace, which is at first quite dark, and only towards the end of the " operation becomes a little lighter, as the gas passes away and the " furnace gets hotter. Thus not only does the operation in the blind " furnace last very much longer (say, twice as long), but it does not on " an average yield as thoroughly decomposed sulphate of soda as that " in open dryers. In the latter the operation is only finished when the " mass has become red hot all through, and when very little gas comes " from it." Vol. 2, p. 792. The fumes from the pan and the roaster pass by the same or separate flues, as the case may be, to the condenser, sometimes to the same condenser, and sometimes to separate condensers, those from the pan to a strong acid condenser, and those from the roaster to a weak acid condenser. When the roasting is completed, the door is opened and the "salt cake" now finished is raked out, usually into iron barrows in which it is wheeled away to a heap of similar cake, usually placed under a shed to protect it from rain. It is here shot down to cool and await the next process.

During the process above described, hydrochloric acid is given off and passes away by the flue. It is not, however, given off equably. The greatest evolution occurs in the course of the first few minutes of the operation and through its earlier portion.

I have said that in addition to hydrochloric acid there may be sulphurous acid in the fume from the salt-cake making. I state this on the authority of Dr. Hewitt, of Richard Bealey and Co.'s works at Radcliffe, Manchester, who tells me that he has ascertained by experiment that some sulphuric acid lost in the process, and first probably coming off as such, finally escapes in this form, being reduced

by the carbonic oxide or the hydro-carbonaceous substances in the furnace and flues. (Open roasters are used in these works.)

But the description I have now given does not exhaust by any means all that ought to be said about the process of salt-cake making. Other methods than those described are in use, and some of these methods must now be mentioned.

Jones's Mechanical Mixer.

There are two kinds of apparatus designed to make salt cake in one process. One of these is "Jones's Mechanical Mixer." It has been patented (1875, No. 1864). It is a large circular flat-bottomed iron pan, made in sections riveted together, and enclosed. In the middle there is an axis, with four arms, provided with iron blades which act as ploughs as the mixer revolves by a gearing outside, and these stir up the material. The sulphuric acid is run in upon the salt from the roof. The entire work is completed in this mixer which serves both as pan and furnace. When the charge has been thoroughly mixed a damper is gradually raised to allow heat from the fire-place to pass over it, and the heat is continued until the process of conversion into salt cake is completed. Various opinions exist as to the success of the mixer for soda, but Dr. Smith tells me that it seems very successful when used for making sulphate of potash. I have been told at several works where this apparatus has been tried that it is very apt to break down. On mentioning this fact to Mr. Jones, he replied that it was due to two causes, one being that the pans had been made too slight, and the other that the makers had neglected to form the junctions of the segments in accordance with another patent (1877, No. 2481) an arrangement designed to obviate fracture due to alternations of temperature. At his works in Middlesborough he showed me a pan duly constructed which worked six tons, and had been in constant use for 18 months without any breakdown. A similar well-constructed pan is also in use at Messrs. Stevenson and Carlisle's works in Glasgow, where it is used for making the potash salt, and gives great satisfaction. The other kind of apparatus that I may mention is the salt-cake furnace of Cammack, Walker, & Co. It consists of a revolving cylinder, which is heated to a red heat by a furnace beneath. There is a spiral arrangement within for causing the materials to pass slowly from one end to the other. The salt and acid are separately supplied in definite quantities at one end, and the finished salt cake passes out by a shoot at the other end. If it were requisite it might be made to pass through a cooler before being finally discharged. The hydrochloric acid passes off by a pipe to the condenser. There are certain advantages apparently in this apparatus. The gases evolved are not mixed with a quantity of air, and so being more concentrated the condenser need not be so large as under ordinary circumstances. Then there is none of that escape of hydrochloric acid which occurs when a pan door is opened for stoking the materials ; and another advantage is, that the evils connected with the cracking of the brickwork in ordinary salt-cake furnaces are avoided. I saw it, but not in use at the time, at Golding, Davis, & Co.'s, at Widnes. It has not yet, I believe, been worked successfully as a commercial process.

Cammack, Walker, & Co.'s revolving cylinder.

Hargreave process.

The next method of making salt cake to be described is that known as Hargreaves' process. One advantage of this is that the process altogether dispenses with the previous manufacture of sulphuric acid. The materials used are sulphurous acid, as it proceeds from the kilns, steam and salt, with admixture of as much air as is necessary to supply an atom of oxygen. The following equation represents the reaction :—

$$\text{Na Cl and } SO_2 \text{ and HO and O} = \text{NaO}, SO_3, \text{ and H Cl.}$$

The plant necessary for this process consists of a series of large iron cylinders vertically set in brickwork. At the Atlas Works at Widnes each cylinder is about 12 feet high and 15 feet diameter, and is capable of containing a charge of about 37 tons of salt. Some cylinders at the Jarrow Chemical Works are said to hold a charge of 50 tons. There is a fire beneath each cylinder, which is encircled by the flues, and the due arrangements of pipes for carrying the sulphurous acid and steam to any of the cylinders that may be in use at the time. There is an opening above for the charging of the cylinder, and a door in the side of the cylinder below for discharging it. A pipe conveys away the hydrochloric acid. One difficulty in the working of this process has consisted in the preparation of the salt, which must be in sufficiently porous masses. This difficulty, to which I need no further allude, has been now overcome. The charge being introduced, heat is applied by means of the fires, but this heat, it is said, is only necessary to commence the operation, the heat of combination being found sufficient to continue the action. The gases continue to be passed in for about 10 days. They are then shut off for a night, air is drawn through the cylinder to remove loose gases, and then the door is opened and the charge drawn. The use of this process appears to be extending. I have seen it at the Atlas Works, Widnes, where the inventor, Mr. Hargreaves, is engaged, at Sullivan & Co.'s, Widnes, and at the Jarrow Chemical Works, and I have heard of its use at other works.

Use of gas instead of coal.

At some works gas is used instead of coal in furnaces for the making of salt cake. The following description (accompanied by a drawing Fig. No. 4, 11th Report) is that given by Dr. A. Smith (11th Report, p. 29) of the arrangement for this purpose in use at Colonel Gamble's Hardshaw Brook Works, at St. Helen's: "Mr. Gamble's salt-cake furnace " is a close roaster or muffle furnace heated by gas, and so arranged that " the pressure in the combustion spaces is greater than that inside the " muffle or inner chamber, where the salt cake is roasted. The conse- " quence of this is that if there are any cracks or leaky places either in " the middle arch" (*i.e.*, the brick arch which forms the roof of the roaster and separates it from the ignited gas flue above it) "or in the " bed, the passage of air is not from the roasting bed into the fire " flues and thence to the chimney, but from the fire flues to the roasting " bed and thence to the muriatic acid condensers. By careful adjust- " ment of the damper in the flue leading to the chimney, the pressures " on the inside and on the outside of the middle arch can be made so " nearly equal that there is very little passage of gas in either direction, " even if the brickwork is somewhat leaky. The increased pressure in " the combustion chambers of the furnace is kept up by admitting the " gas under pressure from a 'producer,' as commonly constructed, and " by admitting the air necessary for its combustion through a nest " of vertical iron pipes 9 feet long. These are warmed by the waste " heat from the furnace. In this way a saving of heat is effected " and the ascending force of a 9 feet column of hot air is gained." During the first two years, Dr. A. Smith says, no repairs were needed, and Colonel Gamble informed me, when I visited his works about a year later, that he had found fewer repairs necessary than in the furnaces heated in the ordinary way.

Making the black ash.

2. *Making the Black Ash.*—Salt cake is mixed with its own weight of crushed limestone or chalk, and with half its own weight of crushed coal or slack, by hand, and the mixture is exposed to a strong heat in a reverberatory furnace, where, through a door in the furnace, a workman stirs up the mixture from time to time to ensure uniformity of decomposition. When the workman judges that the process is completed,

the charge is drawn and carried to the tanks where it is to be lixiviated. Instead of the reverberatory furnace, a revolving black-ash furnace is now used at most of the large alkali works, as, for instance, at the Jarrow Works and at St. Rollox, &c., and has been found to be more productive. It is not necessary to describe it here. But as respects the relative quantities of salt cake and limestone used, an improvement has been effected by Mr. Mactear, by which the quantity of limestone required has been considerably reduced, and thus not only has an economy been effected, but the quantity of waste left by the next process to be described has been also lessened, a point of especial importance when waste has to be subsequently treated for the recovery of the sulphur it contains. Instead of mixing with the salt cake and coal the customary large excess of limestone, he mixes just the equivalent necessary to decompose the sulphate of soda in the revolving furnace, and when all the sulphate has been decomposed the furnace is stopped, and a quantity of caustic lime in pieces is dropped in: the furnace is again started, and the lime mixed through the charge as rapidly as possible, and the whole withdrawn without loss of time. Sometimes he adds with the lime a small quantity of cinders to keep the black ash porous.

Lixiviation.

3. *Lixiviation.*—Each lixiviating tank has a perforated false bottom to support the charge, and when this has been introduced water is run in upon it. When the carbonate of soda has been dissolved out the solution is run off from below, and the tank waste, which when properly drained in the tank should be a mealy blackish grey substance, is carried away to be deposited on the waste heap or otherwise disposed of. (See also p. 219.)

Disposal of the tank waste.

Disposal of the Tank Waste.—In some places, as at the alkali works on the banks of the Tyne, it is a practice to load barges with the waste, and carrying it out to sea there to discharge it. But where this is not done it is the practice to deposit it on the ground usually near the works, but sometimes at some more convenient place at a little distance. As years pass on and the works continue, and become perhaps enlarged, the deposit becomes larger, until thousands of tons have accumulated on the selected spot. Sometimes this spot is some low-lying land, the level of which becomes thus considerably raised; the surface of land thus covered and raised, increasing year after year as the waste is shot round the borders of the former accumulation. Such a deposit may be seen at Roberts, Dale, and Co.'s works at Warrington, where some acres of ground are thus covered. The same thing may be seen in the neighbourhood of Bristol. In other places the deposit forms a heap which sometimes comes to resemble a small hill, as at Chance's works at Oldbury, where the waste is raised to the level of the top of the hill by a mechanical lift.

The form of the heap is a matter of some importance, but whatever its shape it is enlarged by fresh waste being shot down at its end or at the sides in the same way that a railway embankment is made. Newly-deposited waste is customarily patted down firmly. In course of time, as the deposit settles and becomes old, it becomes hard, and in many places roads may be seen cut through it, the section of the heap forming a wall on either side. In some localities the old deposit is used as a residential building site, and it is a common thing to see erections for the purposes of the business put upon such a foundation as this.

Chemical composition of tank waste.

The following analysis of freshly-made waste shows sufficiently the composition of that substance. The analysis was made and kindly supplied to me by Mr. G. E. Davis, one of the sub-inspectors under the Alkali Acts. The waste was the residue of the lixiviation of a black ash prepared with salt-cake, $2\frac{1}{2}$ cwt.; limestone, $2\frac{3}{4}$ cwt.; and slack, $1\frac{1}{2}$ cwt.:—

Analysis of Fresh Waste dried at 100 *C. in a current of Hydrogen.*

Calcium carbonate - - -	26·73
„ oxide - - - -	10·12
„ sulphide - - -	36·60
Magnesia - - - -	1·04
Ferrous sulphide - - -	0·56
Alumina - - -	3·42
Silica - - - - -	5·26
Carbon - - - -	6·20
Soda - - - - -	2·26
Water - - - - -	6·84
	99·03

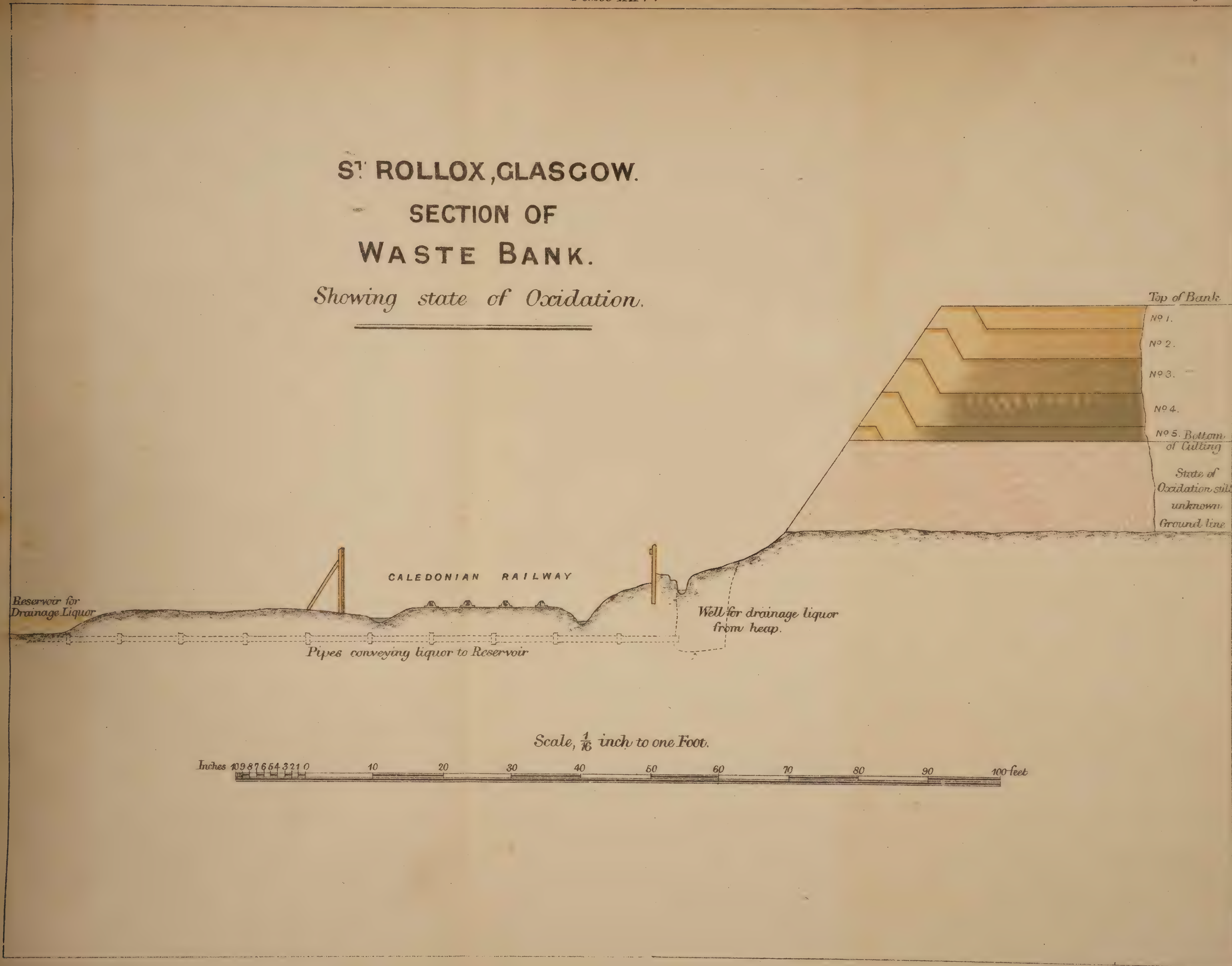
As a waste heap becomes old and weathered, its material undergoes changes, partly due to oxidation by the oxygen of the air and partly due to the solvent action of the rain which it imbibes, and which washes through it, carrying off dissolved matters in the form of a yellow drainage liquor. When the side of an old heap is cut into, it is found that it consists in general terms of a stony hard crust of a deep reddish brown colour, and of little thickness, then of a red hard portion to the depth of a foot, less or more, and that beneath this the material is softer and of a French grey colour, the line where the red colour is replaced by the grey being definite. Plate XXV. is a drawing (for which I am indebted to the kindness of Mr. Mactear) of a section of a waste heap which I saw in course of being cut down (p. 224) at St. Rollox in July last. Five layers are represented and thus described by Mr. Mactear, who has also furnished me with the results of analyses which he made to ascertain the comparative state of oxidation of the various layers. The waste in the lowermost part of the cutting (Nos. 4 and 5) is about 20 years old; it is impossible to say the age of the uncut part below :—

"Comparison of the State of Oxidation of the various Layers of Waste, calculated as if only Calcium Sulphur Compounds were present, as the other substances take no place in the oxidation. Results are given in *percentages* of *sulphur* existing as the following compounds :—

Sulphur as—	New Waste.	No. 1. Layer.	No. 2 Layer.	No. 3 Layer.	No. 4 Layer.	No. 5 Layer.
Sulphide of calcium, CaS	16·80	Nil	Nil	0·90	10·57	8·71
Hyposulphite of lime, CaS_2O_3	·48	Nil	Nil	Nil	Nil	Nil
Sulphite of lime, $CaSO_3$	Nil	10·32	7·32	1·68	·98	·53
Sulphate of lime, $CaSO_4$	·42	2·46	2·26	·39	·39	1·03
Total sulphur -	17·70	12·78	9·58	3·27	11·94	10·27

Table giving the above figures in percentages on the 100 of total Sulphur in the Waste.

Sulphide of calcium -	95·00	—	—	27·83	88·53	84·81
Hyposulphite of lime -	2·70	—	—	—	—	—
Sulphite of lime -	—	80·75	76·41	51·67	8·21	5·16
Sulphate of lime -	2·30	19·25	23·59	20·50	3·26	10·03
	100·00	100·00	100·00	100·00	100·00	100·00



Dangerfield Lith 22 Bedford S^t. Covent Garden

Description of Section of Waste Bank shown in Drawing.

No. 1 Layer.—The sulphide of calcium here has been completely oxidised into sulphite and sulphate. It is uniform throughout its mass. The analysis shows that a considerable amount of the sulphur has been washed out during the oxidation.

No. 2 Layer.—Is also completely oxidised, the analysis giving a slightly higher percentage of sulphate; the total sulphur is lower, showing that more has been washed out than in No. 1.

The section has a slightly darker colour, but no sulphide can be detected.

No. 3 Layer.—The analysis of this one shows that a very large amount of the sulphur compounds has been washed out, only 3·27 per cent. remaining.

This may be accounted for either by its having been exposed for a longer time than the others to the action of the rain, or from its position a greater amount of surface water may have passed through it. (To make sure of its being correct the analysis was checked.) This is the first layer that contains sulphide. When freshly cut, it shows a curious marking, as if it was made up by the two layers immediately above and below it running into each other and interlacing, as shown in the drawing; it shows the oxidation proceeding downwards like the roots of a tree, penetrating into the unoxidised portion.

No. 4 Layer.—Very little altered from the original waste, except that a considerable portion of the sulphur has been washed. Quite dark green in colour.

No. 5 Layer.—Is much the same as No. 4. A little darker still in colour when freshly cut.

The colours of several of the layers shade into one another, commencing as a light-blue grey in No. 1 and ending as a dark olive green in No. 5."

I add three analyses by Mr. G. E. Davis of old waste from three separate localities: in all three instances the material examined appears to have undergone complete oxidation, no sulphide of calcium having been found:—

Analyses of old Tank Waste dried at 100° *C. in a Current of Hydrogen.*

	1.	2.	3.
Calcium carbonate - -	53·50	56·00	45·52
,, sulphite - -	2·63	7·64	26·00
,, sulphate - -	7·00	6·42	1·44
,, silicate - -	17·70	12·46	9·37
Magnesia - - -	0·52	0·44	1·22
Peroxide of iron - -	2·56	1·77	1·44
Alumina - - -	3·44	2·66	3·76
Sulphide of iron - -	·00	1·16	2·11
Carbon - - -	11·00	9·27	6·68
Soda - - -	1·10	1·18	2·26
	99·45	99·00	99·80

No. 1 was from Westfield Street, St. Helens, 15 feet below surface, estimated by residents to be 30 years old.

No. 2 was from Widnes, 8 feet below surface, and estimated at 20 years old.

No. 3 was from the top of a large heap about 70 feet high near St. Helens. The sample was taken 4 feet below surface, and was estimated to be 17 years old.

The manufacture of carbonate of potash from the Stassfurt chloride of potassium, which is an industry apparently on the increase, is in essential points similarly conducted to that of carbonate of soda.

Nuisances from alkali making

The complaints made against alkali works have reference (1) to the injury done by the fumes proceeding from them to vegetation in the neighbourhood and incidentally the rusting effect of them upon metal articles in houses, (2) to the disagreeable character of the acid fumes, and (3) to the injury they inflict upon the health of those exposed to them.

Complaints of injury to property do not fairly come within the purview of this Report. The fact of injury done to vegetation is notorious, and, with qualifications, is admitted on all sides. It is a subject which has been amply discussed by Dr. A. Smith in his several reports to which I may refer. It is quite unnecessary for me to reproduce what he has written about it, and to supplement his account with a summary of what has been said and written by others would be to give to this Report a sensational character, which it has throughout been my endeavour to avoid. The two latter kinds of complaint are properly to be considered here.

from the acid fumes;

The acid fumes from alkali works are without question disagreeable, and in that sense are a nuisance; they are pungent and irritating. But commonly they are mixed with other fumes, such as those of chlorine from the conjoined process of making bleaching-powder, and hence it is not easy always for an inexperienced person to say which kind of fume it is that annoys him. The annoyance is a mixed one, especially in such centres of alkali and bleaching-powder manufacture as St. Helens or Widnes. The fumes are also mixed with coal smoke, in itself acid from the combustion of the sulphur the coal contains, and with the sulphurous or sulphuric acid lost during the process of making sulphuric acid, glass, &c. Dr. Angus Smith thus writes about hydrochloric acid fume, the principal fume from salt-cake making:—"With " 0·0031 per cent. in the air the smell is strong; some persons become " accustomed to more than this amount, but generally it is found impos- " sible to overcome the repulsion to the smell and the inclination to " cough. It is, however, certain that some men keep excellent health, " breathing quantities which are intolerable to others, and others " recover their appetites only in its presence. But the fact of any " substance being in certain cases remedial is no proof of the absence " of deleterious or unpleasant qualities. So in their case, none of these " qualities which make it a favourite with a few men who are compelled " to be in its neighbourhood invalidate the assertion of almost universal " repulsion shown by most men, but especially by women and children, " to the faintest odour of the gas." (1st Report, p. 30.) The nuisance from the acid fumes above described is experienced not only at a distance from the works, where they may fall to the earth after discharge from a tall chimney, but also close around the works, say up to half a mile around them, where, unless in exceptional conditions of atmosphere, the fumes passing from the tall chimney would not fall. The fume may often be seen rolling over the wall enclosing the works as a white cloud, and trailing along above the surface of the ground to a considerable distance before it becomes invisible, and it may be smelt disagreeably far beyond the spot at which it ceases to be seen. The fume discharged from a tall chimney may be disagreeably perceptible even at a distance of several miles, varying with the sort of country the fume is traveling over and the condition of the atmosphere.

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from the tank waste.

But beside the acid fume proceeding from alkali works, there is another and perhaps a still more disagreeable nuisance arising out of the mode in which the tank waste is usually deposited. The gases which are the cause of offence in this case are sulphuretted hydrogen and sometimes sulphurous acid, the latter only when the heap heats and fires. The very offensive smell of the former gas is that to which nearly all the complaints of the tank waste which have been made refer. When walking over a heap of tank waste not decidedly old, there is mostly observable some slight odour of sulphuretted hydrogen emanating from it, but this does not create the nuisance complained of. The chief source of the waste-heap nuisance is that which is washed out of the heap by water. The soluble matter which is washed out is a sulphuretted compound of calcium of indefinite composition, but which mainly consists of sulphide of calcium partly converted by oxidation into hyposulphite of calcium, and holding in solution with it a considerable but indefinite quantity of sulphur. (For composition of this liquor, see p. 224.)

The principal ways in which this solution of the soluble matters of the heap occur may be thus enumerated : 1. Rain falling on the heap and soaking through it may, where the heap stands upon a clayey soil, gradually permeate it until it appears as an oozing at the edges of the base of the heap. 2. The rain falling upon the inclined sides of the heap may wash their surfaces. 3. Springs rising beneath the heap may find issue at the edges of its base. 4. The heap being situated on the bank or banks of a tidal river may be washed at its edges by the water as it rises and falls. The two first ways are the most common ; there is a very remarkable illustration of the third at St. Rollox Works, Glasgow, and of the fourth at Church, near Jarrow. Now what occurs in the first three cases is the production of a reddish liquor which on exposure becomes yellowish, and deposits sulphate of lime with some sulphur. What becomes of this liquor that oozes or is washed out depends upon the nature and conformation of the land. Thus it may form at the side of the heap a little running stream which finds a further course by some roadside or other channel to some neighbouring pond or brook, and then finally into some river; or it may form little pools round about the heap, which in time of rain will overflow and form rivulets in various directions. In dry weather, if the pools be shallow, evaporation may take place, and the pools or puddles of liquor may dry up, and then the only indication of their occasional or former existence may be the yellow stains which they leave upon the surface of the ground. The description I have given must be familiar to anyone who has ever visited St. Helens and Widnes, and such a person must be equally familiar with the all pervading odour of sulphuretted hydrogen which accompanies these appearances. This, however, is not the condition of things which occasions the chief nuisance; but it occasions some of it. The carbonic acid of the atmosphere and the mineral acids, hydrochloric and sulphuric, which the rain washes out of the air in its descent at such places, decompose the lime compounds by entering into combination with the lime, causing at the same time the deposition of sulphur and an evolution of sulphuretted hydrogen. What occasions the greatest nuisance is the admixture of waste acid from the works with the tank-waste liquor in pools, ponds, or brooks. Under ordinary atmospheric influences the decomposition of the liquor is slow and gradual, and the evolution of sulphuretted hydrogen correspondingly gentle. But the mixture of acid directly with the liquor causes an abundant and rapid evolution of this gas sufficient to create one of the most intolerable of nuisances. One of the best illustrations of this last source of nuisance that I met with was at Church, a little village on a tidal stream called the Don,

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which receives abundance of liquor in its course, but the banks of which are formed of waste which is washed and thus made to present a newly exposed surface at each tide. Large quantities of hydrochloric acid are, I am informed by Mr. Spear, the Medical Officer of Health, discharged below the village, and when the tide rises it brings up this acid with it. I never had the misfortune of such an exposure to sulphuretted hydrogen as on crossing the bridge over the river close to St. Bede's Church; it was sickening, and the nuisance strongly pervades the little village.

Injury to health.

from the acid fumes;

With respect to the functional disturbances of the system that are dependent merely upon the impression made by the disagreeable odours upon the senses, there is nothing to add to what has already been said in the introductory part of this Report. From time to time attempts have been made to settle, by reference to the death-rates of the districts where works of this character are found, the vexed question whether they are or not, in a more serious sense, injurious to public health; but all such attempts have failed satisfactorily to solve the problem, and for the very sufficient reason that all are alike vitiated by the impossibility of differentiating the influence exerted upon health by other concurrent conditions.* *A priori*, it

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* I must not, however, neglect to notice an attempt recently made by Mr. Spear, the Medical Officer of Health of South Shields, to apply the statistical method to determine the influence of chemical fumes upon health as indicated by the death-rates of South Shields. In the Appendix to the Report of the Royal Commission on Noxious Vapours (p. 564), he gives a table of the relative mortality from all causes, zymotic diseases, inflammatory diseases of the lungs, phthisis and scrofulous diseases of infants, and convulsions, in three districts into which for the purposes of his inquiry he divides South Shields. In two of these districts, one exposed to the fumes and the other not exposed, he shows that in the year 1875 there was a perceptible excess of mortality under each of the above headings in the former as contrasted with the latter, the character of the population of the two districts being not appreciably different. The comparison, however, is vitiated by the limitation of the inquiry to a single year, which might have been in some way exceptional. Nevertheless, the endeavour to ascertain the truth by this method was praiseworthy, and the extension of the inquiry over a series of years might be productive of some useful results. One point in his paper is specially worthy of mention, namely, the evidence he adduces against the view adopted by some persons that the gases from chemical works may act as preservative against certain diseases. Mr. Spear writes: "It is decidedly, I must say at once, opposed to my experience. I have found "typhoid fever in houses so close to alkali works that the invasion of the gases had "been complained of by the inmates at the very time. In the street which, of all "others perhaps in South Shields is most exposed to such gases, typhoid fever was, "during 1875, on the whole, most prevalent. In Hebburn, a township almost "surrounded by works, I find a more or less severe outbreak of typhoid fever is of "almost yearly occurrence; and in a short street, close by a copper works, scarlet "fever has, during the last year, been in almost every house. I frequently find cases "of typhoid and other fevers in the families of workers in chemical works, "although the atmosphere of their houses is sometimes redolent of the odour of "chlorine and other gases given off from the workmen's clothes. Lastly, several "cases of typhoid fever have in my experience occurred amongst the workers them-"selves. . . . I am decidedly of opinion that in the strength in which they are "found, or could possibly be tolerated, beyond the works they exert no preservative "influence."

Dr. Russell, the Medical Officer of Health for Glasgow, to whose general opinion on the subject I alluded in my First Report (p. 122), has also recently supplied Dr. Angus Smith with statistics of mortality extending over five years, which Dr. Smith has published in his Twelfth and Thirteenth Reports, p. 40. They give no indication that the district to the east of St. Rollox's Alkali Works, which district is most exposed to fume from the works, suffers from the fume in any way that a death-rate will exhibit. The district to the west of the works (Port Dundas), which is less exposed to the fume, had a higher average death-rate both from all causes and from diseases of the lungs (which irritating fumes are believed to aggravate) than the district to the east, which is more exposed. I need not reproduce the tables: it is sufficient to refer to them.

may be said that an atmosphere loaded as the atmosphere of such a town as St. Helens is, with acid fumes cannot possibly be so wholesome to breathe habitually as an atmosphere such as nature has provided; while it must be added that one of the gases emitted, namely, sulphuretted hydrogen, is, when sufficiently concentrated, a poisonous and hence when diluted probably a dangerous and certainly a very suspiciously unwholesome gas to breathe habitually, even in small quantities. Considerations of this kind must be allowed their full weight. Probability is greatly in favour of a decision stamping such effluvia as injurious to health, and therefore naturally and properly gives the mind a bias towards accepting facts that seem to bear in the affirmative rather than in the negative direction; I mean that the criticism which negative facts call forth must necessarily be sharper than that which affirmative facts call forth. Let me give an instance in point. Dr. McNicoll, the Medical Officer of Health at St. Helens, thus states his experience in a paper "On the Noxious Vapours of St. Helens," read before the North-Western Association of Medical Officers of Health in 1876:—"The irritant gases " . . . . do affect the sick-rate of St. Helens, and add to the mortality. " To begin with the aspect of the people, especially of those who dwell " in the immediate neighbourhood of the works; the appearance of these " is sallow and anxious, and presents a marked contrast not only to that " of country people, but of those who live in healthy towns. . . . . " Bearing in mind what these gases are, hydrochloric, sulphurous, and " sulphuric acids and chlorine, you will anticipate my statement that " they injure the organs of respiration by producing bronchitis, asthma, " and sometimes pneumonia." He relates a case in which it was clear to him that the fumes from an alkali work really helped to bring to a fatal termination the pulmonary disease under which two elderly people who resided close to an alkali work suffered, and then he adds, "If we " leave the works and the vicinity of the works, and pass into the other " parts of the borough, we find the effects of the gases less decided. We " cannot charge them with entirely causing lung affections, but in fog " and calm weather they aid predisposition to such diseases, and inten- " sify the attacks." Dr. McNicoll told me that he had found in his practice that bronchitis, asthma, and other pulmonary affections were aggravated when the wind carried the vapours into relation with sufferers from such diseases; and he states in his report for 1874 that he has known "whole bodies of men who were working in the vicinity of an " alkali work leave the place for half a day, because the wind brought " the hydrochloric acid gas so strongly upon them as to cause incessant " cough." On the other hand, Mr. Cooper, the Medical Officer of Health for Widnes, not many miles from St. Helens, told me that, so far as his observation went during the 25 years that he has practised at Widnes, the effluvia from the alkali works produced no injurious effect upon the health of the locality, even as respects the intensification of maladies. He says that the cases of disease which come under his notice do as well at Widnes as in other places. He further said that the children in Widnes are remarkably healthy, and in this respect contrast favourably with the appearance of the children in Liverpool, with which town he is familiar. My own observations on the general aspect of the children I saw playing about in the streets, and of the women standing about at the doors of their houses, were confirmatory of this remark. Dr. Robinson, of Runcorn, who has considerable club practice there, holds similar views upon the subject to Mr. Cooper, and tells me that his experience is that only people with chronic laryngeal affections suffer from the vapours, which, he says, he has not observed to injure phthisical or asthmatic people; and that he has not observed that the presence of the vapours in the

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atmosphere imparts a fatal tendency to disease in general. Mr. Mouritz, the Medical Officer of Health for Runcorn, also says that he has no evidence of any damage done to public health by the works, further than this, that he thinks that the course of pulmonary diseases in persons residing about the works themselves is rendered more unfavourable by the condition of the atmosphere. Now, although there are other circumstances which may and probably do exert an unfavourable influence upon health and the progress of disease in St. Helens beside the fumes from the works, the probability is that Dr. McNicoll is correct in the views he holds, and in attributing to the fumes some at least of the ill effects which he describes. That the evil effects experienced at St. Helens should not be so obvious at Widnes and Runcorn is probably due to the fact that these places are situated on either side of a wide river, the Mersey, along the banks of which they extend for about a mile and a half. This is a tidal river, and there is nearly always a good current of air passing along it, and in this way any stagnation of vapours about the town is prevented. It is otherwise at St. Helens, which is surrounded by chemical works, alkali, bleaching powder, glass works, copper works, &c., and is more densely populated and more closely built in than Widnes and Runcorn, and is so situated as not to be exposed to the constant currents of air that these places are exposed to, so that the vapours pass into the town in any direction of the wind, and are more liable to hang about it.

from the tank waste.

As respects the influence of the sulphuretted hydrogen emitted from the waste-heap liquor when considerable enough in amount to be a great nuisance, the opinions of medical men are uniform and decided. All those to whom I have spoken on the subject concur in saying that such vapours do injure health. Dr. McNicoll, reporting specially on the subject to the Urban Sanitary Authority of St. Helens in 1873, says: "I am not prepared to say that the death-rate of the populations of "these affected districts is greater than the death-rate of other and "more salubrious parts, but I may state it as the opinion of several "medical men, that the *sick-rate* is higher on the easterly parts of "St. Helens than on the more favoured north and west, where these "emanations more rarely come." And in this opinion he himself concurs, and gives it as his opinion further, as respects the Sankey brook into which the drainage from tank waste and waste acid both run, that the emanations from the brook are "deleterious and prejudicial to the health of those who live in the vicinity of it." In a former report he has stated that the depressing influence of the sulphuretted hydrogen rendered convalescence from disease very tedious, and that it was especially obnoxious to infant life. "Our infant mortality," he writes, "is "extremely high, and most epidemics in the town assume a malignant "or typhoid type; and this I attribute to the depressing influence of "sulphuretted hydrogen." Dr. McNicoll's remarks about the Sankey brook refer only to that part of it which lies within the borough of St. Helens, the part at which the first great evolution of gas occurs. But after leaving the boundaries of the borough, the brook proceeds a long and tortuous course through an open country sparsely populated until it reaches Sankey Bridges, near Warrington, where it empties itself into the Mersey. As I could obtain no satisfactory information as to the effect of the effluvia upon public health along this open course of the brook, I made a special inquiry myself, starting at the cottages situated on the banks of the brook at Sankey Bridges, and visiting farmhouses and cottages at intervals along the course of the brook up to the boundaries of the borough of St. Helens. Everywhere that I inquired I found that the nuisance was considerable, though not always uniform in

amount, that the smell entered and pervaded houses, and that silver coins and articles of silver were rapidly tarnished and blackened by the sulphuretted hydrogen. Even at distances of a mile from the brook I heard complaints of the nuisance. But in no instance could I obtain from those I inquired of any admission that would warrant a belief that health had in any way suffered from the nuisance. Nor did I notice in the appearance of the people, adults or children, that I saw, any evidence whatever of interference with the general health. In some of the cottages I called at, indeed, there were children ill or who had recently been ill with measles, but they were none of them suffering severely, and in most cases the illness was so slight that recovery was taking place or had taken place without the necessity of medical attendance. Most of the families I visited had been residing where I found them for many years, and within a few yards of the offensive brook. This observation, however, by no means invalidates that of Dr. McNicoll as to the evil effects of the more concentrated emanations given off within the borough of St. Helens. In the further course of the brook the emanations were much more diluted and mixed with the fresh wholesome air of an open country district, and under these circumstances evidently had no injurious operation upon the health of those of whom I made inquiry. Nor does it invalidate the statement made to the Royal Commission by Canon Hopwood, who resides at some distance from the brook, that its emanations produce a sickening effect upon him personally, inasmuch as rank in life and habitual associations are among the circumstances which modify the operation of bad smells upon individuals. Mr. Gornall, the Medical Officer of Health in this district, who accompanied me in my inquiry, tells me that new comers are those who chiefly complain of injury from the smells proceeding from the brook.

The experiences of Mr. Spear, Medical Officer of Health for Jarrow, as to the effect upon the health of the inhabitants of the village of Church referred to above, where a similar admixture of waste liquor and acid in the river occurs, are in the same direction as those of Dr. McNicoll. The population of the village is 400 or thereabouts, and although the cottages (for the village is only occupied by persons of the labouring class) are old, often dilapidated, and ill arranged, they are freely exposed to the air, and, although the street scavenging is bad, they are not exposed to the entrance of sewer air into them, and there are no accumulations of excrement about them. As to this village, Mr. Spear tells me that the mortality is habitually excessive and much greater than in Pit Cottages, High Street, Jarrow, (about half a mile off,) tenanted by a population as nearly as possible similar, and where the dwellings are in as bad a condition of repair, and in addition unwholesomely exposed to excremental emanations. My own observation of the population of Church was that the residents there are remarkably unhealthy looking, and some of them complained to me that they suffered from headache and sickness when the stench came unusually strongly upon them. The woman who resided at the parsonage house overlooking the river told me that the nuisance had driven away the incumbent, and that since she had lived in the house to take care of it she had suffered much more than formerly from headache and sickness. Prior to that time she had lived in a cottage less exposed to the emanations from the river; but at the parsonage house not only did the stench reach her directly from the river, but it also entered the house by the drains which discharged themselves by a short steep course into the river. Mr. Spear refers to this village in the appendix (before quoted in the footnote, p. 206) to his evidence given before the Noxious Vapours

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Commission. He there states that in 1875 the death-rate in Church was equal to 40 per 1000, and the rate from the seven zymotic diseases to 20 " per 1000. Medical men and old inhabitants," he says, " have told me " that when fever breaks out there it is sure to spread through the place; " and some form or other of zymotic disease is nearly always present."

Wholesomeness of houses built over waste,

The question has more than once arisen in the course of my inquiry whether residences, built upon old tank waste, were rendered from this fact unwholesome, and I have therefore felt it my duty to ascertain what I could upon this subject. Such residences are found abundantly at Warrington (where whole streets have been erected upon the ancient waste from Roberts, Dale, & Co.'s works), at Liverpool, Bristol, and some at Jarrow. The Medical Officer of Health for Warrington reported (April 5, 1875,) to his Sanitary Committee rather strongly about the ill-effect that such foundations had upon the health of the inhabitants of the houses. He also told me that he believed not only that the mortality in these houses was greater than in similar populations in other parts of the town, but that infectious diseases were of a more serious type. He says in his Report that the effects upon health were due both to the pollution of the air and to the contamination of the drinking water obtained from wells in the neighbourhood. He says, " the houses themselves cannot fail to be unhealthy from the generation " of injurious vapours beneath and around the houses, and these " vapours would naturally be attracted to the interior of the dwellings " by means of expansion of the warmer air in that situation." Now, first, it is a fact, for which I have the authority of the late Borough Surveyor, that none of the water supply of these houses is derived from local wells; and secondly, I failed to learn by inquiry that any one complained of any smell entering the houses from their foundations. Neither have I been able to obtain on inquiry any satisfactory evidence that the inhabitants of the houses built upon this particular waste have suffered more from disease or have exhibited a higher mortality than persons of the same class living in other parts of Warrington. But in addition to the Medical Officer of Health, I was informed by Mr. Gornall, the Poor Law Medical Officer, that he found that the people living on the waste were generally " below par " in their state of general health, and that he thought that infectious diseases were more readily taken, and when taken were of a lower type than elsewhere in the town. I give the opinion of this gentleman *quantum valeat*, but I must add that the people did not to my eye look more unhealthy than people of the same class residing elsewhere in the town. I found on inquiry that, although no concrete had been laid upon the waste to form the foundations, there were no indications of the foundations of the houses having sunk or given way The town surveyor tells me that the waste is about 20 years old, and that the first houses were put upon it 17 years ago.

at Warrington;

at Bristol;

St. Philip's Marsh, Bristol, is another place where a number of houses, and even streets of houses, have been erected upon ancient tank waste. A few of the houses in one street have cracked, but not to a serious extent, where the waste had not become previously well settled, but otherwise there has been no evidence of irregular sinking of the houses, which have now been built about 12 years. Here, also, no nuisance has been observed; and Mr. Davies, the Medical Officer of Health, who is an acute observer, tells me that the inhabitants of these houses are not at all remarkable as suffering from ill-health.

at Yarrow;

I met with another instance at Jarrow. One side of Lord Street, Jarrow, is built over a superficial or shallow deposit of old waste, the foundations of the houses resting on the clay: but the other side is not. Mr. Spear tells me that special attention

was paid to the ventilation of the space beneath the floors of the houses by means of flues running up by the chimney. It is a curious fact that the side of the street which is evidently preferred for residence by the labouring population, is the side built on the waste, while many of the houses on the opposite side were vacant at the time of my visit. Except in the case of one house on this side, no residences were complained of when Mr. Spear and myself visited and made inquiries in them. The residents of the houses looked as healthy as most other persons in the district, and I failed to learn that they suffered either exceptional sickness or mortality. The only instance where nuisance was complained of was at a house the rain-water butt of which leaked into the back yard; the water had found its way to beneath the floor boards of the basement rooms, one of which it had rendered damp. In this case there was said to be a smell of sulphuretted hydrogen occasionally. The woman of the house said she had not been in good health during the whole six months she had occupied the house, and a son of hers, residing with her, was suffering from recent dropsy, with which the sulphuretted emanations from the basement had probably less to do than the dampness of the dwelling. I learn from Mr. Spear that since my visit to Jarrow three houses (part of a new street) have been erected in a part where the waste lies from 4 to 5 feet deep, and that one of them, built on the deepest part of the deposit on which its foundations rest, is subsiding. The house has been built about two years, and the floor in one part appears to have sunk about 6 inches. He says the smell of sulphuretted hydrogen is complained of in this house, as also in the one next to it, and the residents are stated to have suffered from nausea and loss of appetite. The site is drained by means of 6 inch drain pipes 4 or 5 feet below the surface, and the drain is always running more or less with liquor.

at Liverpool;

In Liverpool the results of building on tank waste appear to have been very unfavourable. Towards the northern part of that town there is a district comprising a group of streets about what used to be called "Beacon's Gutter," which within the recollection of the present Medical Officer of Health, Dr. Taylor, was waste land, out of which clay had been dug for brick making. The resulting excavations were subsequently filled in with tank waste from neighbouring alkali works, and after a lapse of a few years the streets in question were erected upon it. Shortly after their erection the roadways and houses began to sink in level irregularly, and the houses became offensive from the evolution of sulphuretted hydrogen into them through cracks in the paving of the cellars which were used as dwelling-rooms. At the present time, 25 to 30 years after erection of the houses, the effects of this sinking are very obvious in the fact that the houses in question and the walls of their yards are, along whole streets, considerably out of the perpendicular, and in some places are only kept from falling by beams of timber and other devices for propping them up. It is the opinion of Dr. Taylor and of the engineering officials of the town, that the sinking was due mainly to the flow of liquor out of the waste and its draining off by the sewers, and that the formation of this liquor (considering that the roadways, footpaths, and yards had all been paved) was due chiefly to the escape of water from broken underground waterpipes, and in part also to dilapidations in the yard pavings, &c., which permitted percolation of rain and waste water into the waste beneath. Partly, perhaps, the sinking might have been due to the waste having in those early days been deposited more loosely than it is customary to deposit waste now. Still it appears to be a fact that, since means have been taken to detect speedily fractures or leakages in the sunken waterpipes,

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the injury to the property has ceased to make progress, and the nuisance of the escape of gas into the houses has also ceased to give rise to complaints. Dr. Taylor (who, before his appointment as Medical Officer of Health, was for many years the Chairman of the Health Committee of the Town Council) tells me that it was the opinion of his predecessor, Dr. Trench, that the emanations into the houses damaged the health of the people residing in them, and that he concurs in that opinion,—basing his concurrence on the fact that, notwithstanding the otherwise salubrious nature of the site and notwithstanding that the families occupying the houses have, until quite recently, belonged to a comparatively decent and cleanly class of artizans, epidemic diseases, such as cholera, typhus, and diarrhœa, have habitually made nearly as much havoc among them as among the low Irish population of the close courts in an adjoining part of the town. He could not give me any figures in proof of this assertion, but he showed me some maps of the town marked with dots indicative of deaths from these diseases in the several streets and courts of Liverpool, which certainly appeared to support his views.

It is certain that in time liquor from waste in which sewers and drains are laid does find its way into them, since not only is the liquor found in the sewers giving off disagreeable odours through the street gullies, but deposits take place, which in Bristol and at Liverpool have been found to choke up pipe drains almost entirely. Brick sewers after a few years are seriously damaged. This has been experienced at Liverpool, and I have myself had experience of the same thing at Warrington. In February 1876, Mr. Vawser, who was at that time the Town Surveyor, had a sewer of this kind, which had been constructed at a depth of about 5 feet from the surface only five or six years previously of the best materials obtainable, opened for my inspection. I found it at that time much perished, and the mortar reduced to a powdery condition. Time only will show whether the houses in the streets built upon waste in Warrington will or will not meet with the same fate as those in Liverpool; but there is no indication of it as yet.

So far as any inference can be drawn from what I have thus been able to gather it would appear to be this; viz., that houses erected over old well-consolidated waste are not necessarily unwholesome as residences; nor are they even subject to the nuisance of bad smells from the foundations, so long as the foundations do not give way, and so long as they are kept absolutely dry. But accidental circumstances may reverse these conditions, and then their wholesomeness can scarcely be maintained. The common sense conclusion appears to be that a proposal to erect dwelling-houses upon tank waste is not one to be lightly entertained, and that the use of a site having such contingent liabilities to danger ought unquestionably to be discouraged.

Sources of effluvium nuisances.

I may now proceed to mention those conditions in works which are found by experience to be concerned in the production of nuisance from the operations of alkali making, or from the deposition of tank waste. With respect to the acid fumes from the works, I have already said that they may proceed from the chimney shaft, or from a low level.

1. Proceeding from the chimney.

Mode of condensing acid fumes.

1. First, then, as to those which proceed from the chimney shaft. For many years after the establishment of British alkali works, all the acid generated in the process was habitually discharged into the atmosphere, no attempt being made to arrest it. But in 1836, Mr. W. Gossage introduced into the trade an arrangement for condensing the vapours; and partly on account of the saving it effected, and partly on account of its advantage in reducing complaints of nuisance and damage to crops, it had, by the time that Lord Derby's Bill was introduced into Parliament in 1863, become generally adopted by the trade. The

principle of Mr. Gossage's invention consisted in causing the absorption of the acid vapour by passing it through a high tower filled with coke, down which water was made to percolate. The last portions of gas that might have escaped the solvent action of the water in this tower were arrested by causing the vapour to pass through a second tower. The acid obtained from the first tower was strong enough for use in the manufacture of chlorine; that from the second tower was weak, and was allowed to run away. The Alkali Act, 1863, rendered a process of condensation compulsory in all alkali works in the kingdom, and required a minimum condensation of 95 per cent. of the hydrochloric acid evolved in the work. In 1874 an amended Act was passed, which required in addition that not more than one fifth of a grain of hydrochloric acid shall be contained in each cubic foot of air, smoke, or chimney gases escaping from the works into the atmosphere; and further, that the best practicable means should be used to prevent the discharge of all other noxious gases arising from the work, or of rendering such gases harmless when discharged. These noxious gases are defined to be sulphuric acid, sulphurous acid, nitric acid, or other noxious oxides of nitrogen, sulphuretted hydrogen, and chlorine.

Dr. Smith's observations as to condensers.

The Gossage tower, modified in various ways, forms the basis of the condensation arrangements now in universal use in alkali works. The modifications, as used in different works, will be found described in Dr. Angus Smith's reports. I shall content myself therefore with summarising here what Dr. Angus Smith says generally about condensation and condensers. He points out :—1°. That the agencies in use are mainly cold and water; but that their operation is favoured by an extension of surface, and by giving a sufficient time for the exertion of their influence upon the vapours. It is to extend surface that coke is introduced into the towers, and the importance of time is shown by the fact that "gas is frequently dragged so rapidly through a large and otherwise efficient condenser as to pass out little affected." (1st Report, p. 16.) With respect to the value of coke as a packing for a condensing tower, Mr. A. E. Fletcher mentions an instance within his observation where it turned out that there was sufficient steam given off with the muriatic acid to liquefy the whole without addition of water. In this instance the gases were passed through a long series of earthern pipes, and thus condensed by cooling. What remained was passed on into a tower filled with coke, and thence to a final flush tower. He adds, that it was found "that when no water is admitted to this coke tower a "more concentrated liquid muriatic acid is condensed in it than in "the long series of cooling pipes through which it previously passes." 2°. It is necessary to efficient condensation that the hot gases from the roaster should be cooled before they enter the condenser. This is usually effected by allowing them to pass, on their way to the condenser, along earthenware pipes for a great distance. Glass, instead of earthenware, has been used advantageously as a material for the cooling pipe. (11th Report, p. 29.)

Defects of condensation.

The chief circumstances which appear from Dr. Smith's reports to have been most effectual in hindering the good operation of condensation arrangements, and thus in favouring escape of uncondensed gas from the chimney, are the following :—1°. Too strong a chimney draught, insufficient time being thus afforded for condensation to take place. Dr. A. Smith (4th Report, p. 49) says that "the Belgian Commission "was of opinion that the condensing apparatus ought not to be in communication with high chimneys," and that he "had frequently had occasion to advise a weaker draught." 2°. Bad packing of the coke tower, the packing being too loose or too tight, or the pieces of coke being too

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large. When square condensers are in use, the packing "seems very "liable to settle after being in use for some time, and by so doing the sharp "angles, however carefully packed at first, become a sort of passage for "the gas"(4th Report, p. 37). 3°. The condenser inclining from the perpendicular, so that the water does not fall down equally; the gas in this case passes through the dry portion in preference to the wet portion, because there is less obstruction (1st Report, p. 22). 4°. Insufficient size of condenser. 5°. Too much water, the excess preventing the action of the coke; or too little water. "Many and shallow streams are wanted." 6°. Improper direction of the current of gas. "It would seem that when the stream of water meets the stream of "gas going up, the condensation is much better than when the water and "gas come down together; for this reason, to make a double condenser, "or one divided into two parts, the gas going up one side and down "another is a mistake. The gas when it goes up one side may be led "down by an earthenware tube to the bottom of the other side, up "which it will go." (1st Report, p. 23). 7°. Insufficient previous cooling of the gases. If not cooled enough the condenser may become so heated that the water run down will be warm instead of cold, and then not sufficiently absorbent of the gases. In one instance mentioned by Dr. Smith the gases entered the condensers so hot that the coke took fire. "Long cooling-tubes diminish the necessity for the largest sized condensers (1st Report, p. 23). More cooling is requisite than under other circumstances where Hargreave's process is used, since all the heat caused by the combustion of the pyrites as well as that of combustion has to be dealt with (11th Report, p. 38). 8°. Leakage from close furnaces may be the cause of escape of acid by the chimney, since the tendency of the gases would be (partly from pressure within the close roaster, and partly from the suction influence of the chimney draught) to pass through any cracks or leaks from the roaster into the chimney, which under ordinary circumstances would conduct smoke only. This, Dr. Smith says, "seems to take place even in cases where "the brickwork is extremely thick. The parts most apt to leak are "round pans without rims and the arch of the furnace" (4th Report, p. 46, where this subject is fully discussed). In Dr. Smith's 1st Report, (p. 12) he says that (up to that time) close furnaces had given the best results, so far as condensation was concerned; but very early in the working of the Alkali Acts he found an instance in which (p. 12) excellent condensation had been effected with open roasters. Later on (3rd Report, p. 41) he stated that several works with open roasters condensed all their gases. (*See further* p. 293.)

2. Proceeding from a low level.

2. Secondly, as to those which proceed from the works at a low level. The ordinary causes of nuisance from a low level are the following:— 1°. Deficient draught in the flues. This may, again, be due to various structural defects, such as insufficient capacity or too tight packing of the condenser. When there is insufficient draught, not only will gas escape at any cracks or fissures about the apparatus, but much more freely when the furnace is opened for the purpose of stirring the charge or drawing it. 2°. The escape of acid gases from the charge when freshly drawn. So far as my experience goes, this is perhaps the most common cause of the low level nuisance. I have never seen a charge drawn in the ordinary way from an ordinary furnace without some escape of this kind taking place; but the escape is greatest when a charge is drawn too early and before it has been sufficiently roasted. 3°. Leaks about the apparatus.

The sources of the tank-waste nuisance have been partially referred to in an earlier part of this section of my report. They are the evolu-

tion of sulphuretted hydrogen when the material becomes heated by oxidation, and of sulphurous acid when it takes fire. But these nuisances only occur when the waste is carelessly deposited. If there were no liquor running from the waste there would, with the exercise of ordinary care, be little atmospheric pollution, and hence primarily the chief causes of the nuisance are those which promote the solution of the sulphur salts of the heap before oxidation has fully converted them into sulphates. Among these I may mention the following as the most important, so far as I have been able to observe. 1°. A site where springs issue from the surface ;* a site in a hollow where rain falling on the ground naturally gravitates towards the base of the heap, or a site upon land liable to become flooded. In the first case, a constant flow of liquor takes place from the solution of the soluble matters in the heap by the water springing out of the soil. This is the case at St. Rollox Works in Glasgow, where the accident, however, is now turned to good purpose, as will be shown later on in this section (p. 223). In the other cases, the edge of the heap is exposed to the solvent action of the water lying round its base. Under these circumstances, also, portions of waste shot down at the top of the heap roll down its slope into the water at its base. The case is worse where, as at Church, Jarrow, the heap is washed by a tidal river. 2°. A wet condition of the tank waste as deposited on the heap ; the waste in the tanks being "sludgy" or "slutched," as it is called, in which case it will not drain properly in the tanks. The waste should be "mealy." Alkali makers with whom I have talked on the subject of "slutched" waste tell me that it mainly arises from the following causes ; viz., some fault in the selection or due preparation of the materials used to make the black-ash, imperfect manipulation in the black ash furnace, or too great haste in removing the waste before it is fully drained. In illustration of the first of these causes, the foreman of C. J. Schofield's Works informed me that, at the time when coal was very dear, when they purchased what they wanted from comparatively cheap sources instead of the coal which suited their work best, they commonly got "slutched" waste. He further said that where caustic soda is made it is customary to mix the waste lime of this process with an equal proportion of crushed limestone, and that this proceeding imparts the same character to the waste. In illustration of the second of these causes, the same person informed me that if the furnace be not hot enough (as happens sometimes on Mondays), or if the firing be continued too long so as to burn out all the slack before the complete decomposition of the sulphate of soda, the same thing will happen. Speaking to Mr. Dale upon the subject subsequently, he said that when waste "slutches," an extra quantity of slack will sometimes remedy the evil, and this seems to confirm what this foreman told me. In addition to all this, Mr. Schofield's foreman said, as a matter of practical observation, that furnaces even had their peculiarities which the firemen employed at them have to study and learn by experience ; and hence that, at works where these men are frequently being changed, there is less certainty of a good black ash being made that will furnish a mealy waste than where the same men work long at the same furnaces. Mr. Wrigley, of Bury, whose waste heap is especially dry and devoid of nuisance, gave testimony in much the same direction as the above, attributing the condition of his waste heap not so much to a careful selection of coal and limestone, as to the fact of their works being small,

* Such sites, however, are advantageous where the drainage is to be preserved for subsequent treatment.

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and of the strict control they can and do exercise over the work carried on at the furnaces and lixiviating tanks. In illustration of the third cause, Mr. Schofield said that at works where there is insufficient tank plant for the work required to be done, the waste is removed too early from the tanks, especially in seasons of great demand. 3°. When a heap is constructed so as to afford a broad surface at the top, this surface in time sinks in the middle or is worn down there by the weight of trollies passing over it. Under the most favourable conditions a broad surface is afforded for the reception and imbibition of rain, but when the surface has concavities, however shallow, upon it, the lodgment of rain is promoted thereby. Soaking into the heap it filters through, and the water appears at the edges carrying with it dissolved matters. Moreover, if the waste shot down at the end or sides of the heap is not sufficiently patted down so as to exclude air and enable water to run off without being much absorbed, not only is the proper surface drainage of the heap interfered with, but the matter so deposited locally is apt to take fire, and then sulphurous fumes are diffused about its neighbourhood.

Modes of preventing nuisances.

As to the remedies applicable to the several kinds of nuisance from alkali works.

1. High level nuisance.

1. *For the High-level Nuisance.*—The inordinate escape of acid fumes from the chimney. The discovery and application of remedies for this nuisance have for many years past been the work of the inspector under the Alkali Acts, and all that is known practically on the subject is to be found in Dr. A. Smith's valuable reports. Referring to the several causes of inordinate escape enumerated at p. 213 of this Report, the remedies for those numbered 1° to 7° are obvious as soon as the causes of the nuisance have been mentioned. They consist in the due regulation of the draught in the chimneys and flues, the proper cooling of the gas and the proper packing of the condenser, the adaptation of the capacity of the condenser to the extent and character of the work done, and the due regulation of the supply of water, and any alteration that may be needed to restore perpendicularity to the condenser, and a proper direction to the flow of gas through it, &c. But as respects close furnaces some further remarks of Dr. A. Smith should be quoted.

In the first place, he leads us to infer (7th Report, p. 77) that the leakage from close furnaces would be less if the work were not driven forward so violently as is customary in England; since he says that in Scotland and Ireland, where the work is not driven forward violently, the close furnaces do not allow much leakage. In the second place, he recommends "the introduction of decomposing pans, which "shall prevent the escape of gas into the flues." "The liability," he says, "to leakage in the brick setting is great, if there is any passage "whatever from the flue to the upper portion of the pan. It is not "sufficient that the intermediate space should be filled up with "bricks. Bricks have been regarded as fire tubes conveying the gas, "whenever the construction is such that the draught produces a pres- "sure against them. But even when this view of the structure of "brick is impossible, namely, when there is a thick glaze upon them, "the openings apt to form at the junctures by frequent changes of "temperature render them badly fitted for inclosing gases." (6th Report, p. 56). In the third place he says, "the modes adopted for "keeping down the amount of escaping gas are not sufficiently self- "acting; they require a great deal of attention. . . . Since it "does not seem possible to make the middle arch capable of resist- "ing leakage for a long time, it is clearly safer to adopt some method "of condensing that which passes into the flue, than to be obliged "continually to make repairs. The addition of a small Gossage tower

" has been found sufficient. It is also possible to increase the draught " of the condenser to a greater extent than that of the furnace, " but this method requires a very large condenser, the close packing " of which in later years has rendered rapid ventilation through them " more difficult than it used to be, with those who have determined " on this improvement. The inclination appears to be to adopt the " plan of washing the furnace-flue gas. . . . . In any case it is " important that less ought to depend on the vigilance of the men" (6th Report, p. 55). In the fourth place, he quotes the experience of good results obtained in one establishment by heating the bed of the furnace only (6th Report, p. 66). " The fire does not pass round, so that no double arch is needed." Dr. Smith gives a plan illustrative of this mode of heating, and in his 7th Report, (p. 77), he says, "It is " probable that the middle arch will soon cease to be used; where it " exists there ought always to be a smoke washer or tower on the fire " flue." At Col. Gamble's Hardshaw Brook Works, at St. Helens, where gas is used to heat the close roaster or muffle furnace, the difficulty is met in another way, (see p. 200).

2. Low level nuisances.

2. *For the Low-level Nuisance.*—Sometimes this may be lessened by improving the draught in various ways, closing leaks, &c.; but constantly there is some escape at the time that the charge is being drawn. At some works a hood or hopper has been constructed over the furnace door. Dr. A. Smith, in his 4th Annual Report, gives a plate showing the arrangement of hoods at the Walker Alkali Works, at Newcastle-on-Tyne, and in the 11th Report, p. 30, he gives a description of the hood I have seen in use at the Bridgewater Chemical Works at St. Helens, and also a drawing of it. It projects so far beyond the mouth of the roasters as to catch the fumes proceeding from the barrows during their loading, as well as that from the furnace door. The pipe issuing from the top of the hood leads to the chimney; practically there is little objection to this. The use of such a hood or hopper as this affords time for the efficient use of the next proceeding, which ought to be always adopted, namely, the covering of the hot and freshly-drawn salt cake with cold salt cake patted down upon it before the barrow is wheeled away. Workmen often neglect this precaution, on account of the trouble of bringing cold salt cake to the mouth of the furnaces. Lastly, care should be taken that the charge is not drawn too soon. At Messrs. Howarth's works at Manchester there is an iron chamber or box, having folding doors in front and a flap cover above, fixed in front of the door of each roaster, into which box the charge is drawn, and where it can be left for an hour to cool before being wheeled away. A pipe from the summit of this box leads to the condenser. At the Netham Works the charge from the roaster is drawn through an aperture provided in the floor of the roaster into a space below, closed in front by an iron plate with an aperture in it for the admission of air. The fresh salt cake is left here to cool for half an hour, the acid vapours passing by a flue from the chamber to the chimney, the draught of which is sufficient to cause an influx of air into the chamber through the hole in the closing plate. It is a contrivance which certainly considerably diminishes the nuisance. With the adoption of the Hargreave process the low-level nuisance is entirely avoided. The salt cake drawn out of the cylinder gives off no acid vapour perceptible to the senses. I have seen charges drawn at different works, and this was my invariable experience. The use of Jones' mechanical mixer will also obviate this source of nuisance. At Mr. Jones' works at Middlesborough a charge was drawn during my visit, and there was no perceptible issue of gas

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3. The tank-waste nuisance.

from the drawn charge. Messrs. Hunt, of Castleford, who use this mixer exclusively, also inform me that this is their invariable experience.

3. *For the Tank-waste Nuisance.*—1. As respects the situation of the heap: the manufacturer may have no choice in the matter. If he is to make a heap at all he must make it where it may be most convenient to deposit his waste. But it occurs to me to suggest that something might probably be done in the case of new heaps to prepare the ground for the deposit so as to provide artificial means of drainage. At the works of Messrs. Hunt Brothers, at Castleford, where the waste is deposited upon land subject to being much flooded occasionally, a layer of furnace clinkers 2 or 3 feet in thickness has been first put down, and upon this the waste has been laid. A constantly dry foundation has thus been obtained. The practice at these works suggests an appropriate foundation for a heap. The surface of the ground properly sloped might be first covered, for instance, with an impermeable material, and this by a layer of clinkers, and the liquids which drain through from the heap might, I imagine, be prevented by due arrangement from running over the surface of the adjoining land, and be conducted away either to an appropriate receptacle (should it be intended to utilise the liquor), or underground to the natural drainage outlet. At least some proper drainage arrangements ought to be provided at the sides of a heap. 2. The form of the heap appears to me to be a matter that ought to be well considered. The heaps that I have seen to be productive of least nuisance have been in the form of an elongated, comparatively narrow mound like a railway embankment, of no greater width at the top than has sufficed for the convenient carriage of waste along it. It has occurred to me (and the feasibility of the suggestion is a thing for manufacturers to consider), that where an extensive broad area of land has to be covered or filled in with waste it would be better to deposit the waste in a series of such banks or ridges, side by side, than to spread it uniformly. There would thus be given facilities for drainage between the ridges. At all times it is most important that there should be no neglect in the patting down firmly of all freshly-deposited waste at the end or sides of a heap, a proceeding which, by excluding the air, is calculated to obviate the rapid oxidation which causes inordinate heating and ignition.

It has been mentioned that the principal evolution of sulphuretted hydrogen takes place when waste acid discharged from the works comes in contact with the liquor from the heaps. This necessarily takes place when the weak acid from the condensers is discharged into brooks or drains into which this liquor also runs. For this there are two remedies applicable. The one is to run off the waste acid carefully and separately into an outlet, such as a sufficiently wide river, where the admixture may take place without creating nuisance, and the other is to make no weak acid at all, which is accomplished by using the weak acid instead of water in the first condensers. As to the first of these remedies, it was given in evidence before the Commission that there must be some mode of getting rid of waste acid in some places, since already more acid is condensed than can be used at the works, or than a sale can be found for (2816).

Recovery of sulphur from waste and waste liquor.

The discovery within recent years of modes of recovering sulphur from tank waste and from the yellow liquor issuing from waste heaps is calculated, although to an extent yet not ascertained, to lessen this nuisance.

Mond's process.

The first process to be mentioned is that invented and patented by Mr. Mond, but the patent has now expired. It is applied to fresh tank

waste. The following is Mr. Mond's own account of his process, as given in a paper he read before the British Association in 1868:— The process is "based on the following reactions;—1st. The conversion "of the insoluble compounds of calcium and sulphur in the waste into "soluble compounds by the action of the oxygen of the atmospheric "air. 2nd. The removal of these soluble compounds from the rest of "the waste by lixiviation with water; and 3rd. The separation of "the sulphur from the liquors so obtained by muriatic acid . . . ." "The process is carried out in the following way:—The first product "of Leblanc's famous process for the manufacture of soda, called rough "soda or black ash, is now almost universally lixiviated with water in "an apparatus which was first used for this purpose in Great Britain, "and is composed of a number of square iron tanks, connected in a "very simple and ingenious way by pipes and taps to allow the water "to enter a tank filled with black ash already nearly spent, and thence "to flow through others filled with black ash richer and richer in "alkali, until it meets fresh black ash in the last tank, thus becoming an "almost concentrated solution of alkali before leaving the apparatus. "The alkali waste or insoluble residue of the black ash remains thus "in these tanks deprived of all alkali, and as it has been immersed in "the liquor throughout the whole time of lixiviation, it is consequently "obtained in a very porous condition. These tanks are always pro- "vided with a perforated false bottom, and for the purpose of applying "my method the space between the two bottoms of each tank is con- "nected with a fan by a pipe with a damper, to allow of the regulation "of the quantity of air entering the tank. The pressure of air required "never exceeds 6 inches of water, but usually as little as half an inch "of water is sufficient, and can thus easily be produced by a common "smithy fan. As soon as the last weak alkali liquor is drained off the "waste, the damper in the air-pipe is drawn, and air forced through the "waste. The waste soon begins to heat, rising up to 200° F.; it gives "off quantities of steam, and becomes gradually covered by spots of a "bright yellow colour, which, together with the temperature of the "waste and the quantities of steam passing off, enables the workman "to judge very well when the proper state of oxidation has been "reached. Usually this is arrived at after 12 to 16 hours' blowing. "The oxidised waste is then covered and completely lixiviated with "water. As soon as the resulting liquor is drawn off air is again "forced through the waste in exactly the same way as before, the "waste is again lixiviated, and subsequently this treatment is repeated "a third time. The weaker liquors so obtained are passed through one "or more tanks filled with oxidised waste, so as to concentrate them. ". . . . . The whole process of oxidation and lixiviation of the "waste, though it is repeated three times, is finished in from 60 to "72 hours, and does not require more than one and a half times the "number of tanks which are generally used for the simple process of "the lixiviation of the black ash. In most works sets of four tanks "are employed for this latter purpose, and these have thus to be con- "verted into sets of ten, all of which are to be connected in the usual "way by pipes and taps, and are also to be connected to a fan. Four "of these ten tanks are always filled with black ash in the course of "lixiviation, and the remaining six with waste undergoing the treat- "ment by my process. As soon as this treatment is finished the "waste is thrown out of the tanks, and these are again filled with black "ash to be lixiviated in the usual way, so that both the process of the "lixiviation of the black ash and the extraction of sulphur from "the waste are carried on continuously and without interruption.

"When the waste leaves the tanks, all the recoverable sulphur has been "taken out of it; it contains only small quantities of sulphides, which "are so enveloped by other compounds that they are no longer acted "upon by the oxygen of the air, and can thus no more give rise to the "dreadful exhalations of sulphuretted hydrogen, or to the formation of "those well-known yellow drainage liquors which have hitherto caused "the waste to be so great a nuisance, the one poisoning the air and the "other the water, in the neighbourhood of the vast heaps of waste sur-"rounding many works. Almost all the sulphur left in the waste "exists in the form of sulphite and sulphate of calcium, which are "both quite innoxious, together with the carbonate and hydrated "oxide of calcium, as well as with a little soda . . . . The liquor "thus obtained, which is usually called 'sulphur-liquor,' is of a deep "yellow colour, and contains from four to seven per cent. of sulphur in "solution. This sulphur is present principally in the forms of hypo-"sulphite, polysulphide, and sulphydrate of calcium. Usually the "oxidation of the waste is so regulated as to obtain liquors containing "as nearly as possible so much oxygen in the form of hyposulphurous "acid as is necessary to oxidise both the calcium and the hydrogen "existing as polysulphide and sulphydrate. These liquors are run into "wooden vessels together with an equivalent quantity of muriatic "acid, and steam is at the same time introduced so as to keep the tem-"perature of the mixing liquids between 140° and 150° F. The "proportions of liquor and acid can be easily and very correctly "regulated by the workman according to the colour of the mixing "liquids in different parts of the vessel. Black where the liquor comes "in, it changes to grey and white, turning into a bright yellow "where the acid meets the liquid. At the temperature mentioned, "neither sulphuretted hydrogen nor sulphurous acid are given off in "appreciable quantities, but nearly all the sulphur contained in the "liquor is precipitated in a very pure state. When the vessel is full of "liquid, it is allowed to stand a few hours; the sulphur settles very "rapidly to the bottom, and the clear supernatant liquor, which now "contains principally chloride of calcium, and generally not more than "one thousandth part of either free acid or hyposulphite of calcium, is "then run off. The vessel is now filled a second and usually a third "time with liquor and acid, and the sulphur which has then accumu-"lated in it is drawn out by a door at the lower end of the vessel into "a wooden box with a perforated false bottom. Here it is well washed "with water, and after having been drained is melted down in an iron "pot or pan. It is thus obtained very pure, containing less than "one per cent. of impurity, and surpassing in this respect all brimstone "which is imported into this country.

"The principal constituents of the liquor are determined in the "following way:—The hyposulphite is tested as usual by a solution of "iodine and starch, after addition of acetate of zinc. Another portion "of the liquor is tested directly by iodine and starch; the blue colour "is then taken away by a drop of hyposulphite of sodium, and litmus "and a caustic soda solution is added until all free acid is neutralized. "This free acid is equivalent to the sulphuretted hydrogen in the "liquor, and the three tests lead by a very simple calculation to the "calcium present as polysulphide. This polysulphide containing "usually only little more than two equivalents of sulphur to one of "calcium, the test gives also approximately the amount of sulphur in "these liquors. If the proportion of hyposulphite to sulphide has "been quite correct, the iodine used for the first test will be one-fifth "of the iodine used for the second test. In practice the liquors will of

" course deviate a little from these proportions ; they are, however, kept " within so narrow limits that none of the firms who have so far " adopted the process have considered it worth their while to avail " themselves of the very simple means which I have proposed for " remedying any irregularity, such as keeping a small stock of liquor " rich in either hyposulphite or sulphides which the workmen might " add in case of any gas being evolved during the precipitation of the " sulphur. The vessels in which this latter process is conducted are, " however, always loosely covered in and connected with a chimney, " so that any gases which might be evolved by accident are carried off; " or they are still better connected with the fan forcing the air through " the waste, so that these gases may be absorbed in passing through " the waste, and thus the sulphur which they contain may also be " saved."

At Messrs. Muspratt's works at Widnes the waste is not blown in the lixiviating tanks, but is at once transferred from them into iron tanks, which may be of any convenient size, but which at these works are 12 or 14 feet square and about 5 feet high. Each tank has a perforated false bottom raised about 6 inches from the true bottom, and on this the fresh waste is laid to a depth of about 4 feet. Air is slowly blown in below the false bottom by means of a Roots' blower for six or seven hours. The blown waste is then lixiviated, and the solution drawn off, and then the waste is blown a second time; and this alternate blowing and lixiviation is repeated four or even five times. Mr. Edmund Muspratt, however, tells me that there is little profit in blowing more than three times. When the liquor has arrived at the desired strength it is pumped up from the store tank into a large wooden vat provided with a mechanical stirrer. This vat is covered and only open to a small extent, where the shaft of the agitator passes through the cover. A discharge pipe, for the escape of gases evolved, passes up from the vat to above the head of the workman who stands upon the cover to regulate the flow of the acid which is run in, the quantity run in being regulated by the taste. Mr. E. Muspratt tells me that in his experience 65 per cent. of the recoverable sulphur is recovered at his works. The contents of the vat, when the decomposition is completed, are run off into tanks having false bottoms of canvas which filter out the sulphur, the liquid being permitted to run away.

At Messrs. Thomas & Co.'s works, at Avonbank, near Bristol, the process is made continuous, liquor and acid continuously running into the decomposing vat, and the precipitated liquor continuously running out. The proportion of acid is regulated by the degree of acidity of the effluent liquor, as tested by test paper at the exit channel. This liquor should be feebly acid. The contents of the decomposing vat are maintained by steam heat at a temperature of about 140°. Filtration is not used at these works, but the liquid with its precipitate is run off by open wooden channels into settling tanks, where the deposit of the precipitate takes place. Mr. Carpenter, a member of the firm, says that this precipitate consists of a mixture of sulphur and sulphate of lime. To separate these the drained precipitate is introduced into a close iron vessel or boiler into which steam (30 lbs. to 1 inch pressure) is thrown. The sulphur is thus melted, and the contents of the vessel separate into two layers, one of melted sulphur below, and the other of sulphate of lime slush above. In order to separate arsenic from the sulphur a little sulphide of calcium (some undecomposed liquor practically) is added to the contents of the vessel) and the sulphide of arsenic then formed remains in the slush. The contents are then blown out through a pipe reaching to the bottom of the vessel—first the sulphur and then the

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slush. At the Netham works the blowing is performed, without transference of the waste, in the lixiviating tanks.

Occasional nuisance from Mond's process.

The fact that either sulphuretted hydrogen, if the waste have been insufficiently blown, or sulphurous acid if it have been too much blown, may be given off during the process of precipitation, is sufficient to indicate that this process may not always be conducted so as not to occasion nuisance. Indeed Mr. Carpenter told me that at one time the sulphuretted hydrogen from their recovery process was complained of at a distance of 200 yards from the decomposing tank, and I myself noticed at one work I visited an abundant evolution of sulphurous acid, not only from the decomposing tank but from the liquor as it ran from it to the settling tanks. Some evolution of sulphuretted hydrogen even takes place during the blowing process. In fact it appears to me that there is as yet in practice a lack of that precision in this process of which it is doubtless capable. For one thing, the blowing is not always as uniform in practice as it is in theory. The holes in the false bottom of the tank, for instance, are apt to become irregularly choked up and have to be punched clear again before each fresh blowing, and this is the sort of thing workmen are apt to neglect. In one instance that I especially noticed, air was blowing out more freely near the sides of the tank, where it had made for itself channels through the stuff, than in the middle. Talking to Mr. Mond upon this subject, he said that this was apt to take place when the waste was transferred from the lixiviating tanks to be blown, unless it were very dry before its transference, and that it is less likely to happen when the waste is blown in the lixiviating tanks themselves, as he has advised. He said that there should be no hurry in the blowing, and hence that there ought to be an abundance of tank plant provided, and the blowing should be regulated by the use of an anemometer. But it is not easy to get workmen to carry out precise work. He further said that, if the chemical composition of the liquor obtained be correct, there will be no evolution of sulphuretted hydrogen, and that the best way to avoid it in practice is to keep on stock in a separate vessel a quantity of liquor from overblown waste, and, should any evolution of sulphuretted hydrogen occur during the precipitation process, as much of this liquor as may be necessary should be added to that which is being operated on. At Thomas' works the nuisance due to the escape of sulphuretted hydrogen from the precipitating vat is obviated now by conveying off the evolved gas by a pipe, and making it pass through several layers of hydrated peroxide of iron laid upon trays in a brick chamber open above, and protected from the rain by a shed. The passage of the gas into this apparatus is promoted by a jet of steam thrown into the pipe. There is a similar provision against nuisance at the Netham works, but here the apparatus is charged with sulphate of iron.

The waste fully and properly treated by Mond's process is, so far as my observation goes, no longer a source of nuisance, but it would appear from the evidence given before the Noxious Vapours Commission, that this is not the universal experience. All however appear to admit that if by this means the whole of the nuisance is not removed, it is lessened in a considerable degree. Something of course will depend upon the extent to which the separation of the sulphur is carried at individual works, and this again will depend upon the profit derivable from its separation as completely as possible. In Mr. Mond's evidence he says (4951) :—"In those works where my process is properly applied "the waste is absolutely innoxious, but there are only one or two works "in this country which do work the process for the purpose of making

" the waste innoxious; the others are working it for the purpose of " profit, and as no profit is to be obtained by getting the last quantity " of sulphur out of the waste, they do not go to the trouble of oxi- " dizing it as far as is necessary to make it innoxious." Again he says (4966), "The process cannot extract more than half [of the sulphur in " the waste]; it is even difficult to obtain more than a third of the " sulphur; but the waste after one third of the sulphur has been " extracted, if properly treated, does no longer give rise to the evolution " of the yellow liquors." "It is better than other waste in any case," (4967). Mr. P. J. Worsley, the managing director of the Netham works, where about one fifth only of the sulphur in the waste is recovered, gave the Commission evidence to the same effect. He says (6332), " The waste from which the sulphur has been recovered becomes " innoxious much more quickly than waste not so treated. The waste " from the recovery process becomes inodorous under favourable circum- " stances in a fortnight or three weeks time. During this time there is " no drainage from the waste, and from the waste that has become " inodorous the drainage is inoffensive." He adds (6380) that the waste thus treated "gives off a certain amount of smell, perhaps rather more " than the ordinary waste, for a few weeks, until it has become " thoroughly oxidized by the air, but after that time it can give off " no smell whatever; it is absolutely safe. The other waste, of course, " is liable, if any carbonic acid in the air gets near it, to go on giving out " a smell for a very great number of years." Major T. Cross informed the Commission (6129) that he found the evolution of sulphuretted hydrogen from the treated waste so great a nuisance, and the waste so likely to take fire, that he was obliged to cover it after its deposition with some ordinary waste. I do not see why so simple a precaution, with a good patting down of the untreated waste or some clay over the treated waste, should not be habitually adopted in such cases. The waste, however, treated by Mond's process appears to lose its binding qualities, it is loose and light. Hence it is less adapted than untreated waste to deposition in a mound, but it is well adapted for filling in and raising the level of low land such as that about the works at Warrington, and it is so used at Avonbank. Recurring to the question of profit (a most important consideration when it is suggested that a manufacturer should carry out any particular process) the evidence of Mr. Worsley must not be overlooked; it was to the effect that while the adoption of Mond's process by a few manufacturers might not be unremunerative, it would, by cheapening sulphur, cease to be remunerative if it were largely adopted in the trade.

Mactear's process.

The other process for recovery of sulphur discovered by Mr. Mactear, of the St. Rollox Works, Glasgow, is applied to the liquor draining from the waste heaps, and has been patented (1871, No. 2374). So far as I am aware it is only in use at the St. Rollox Works, where various improvements on the process have been been effected since the patent was taken out. It is to be observed, however, that the waste heaps at St. Rollox, which are very extensive indeed, in consequence of the long number of years that the works have been in operation, are somewhat peculiarly situated as respects the flow of liquid, inasmuch as numerous springs under the heaps cause the issue of a large, constant, and very regular supply of liquor. This liquor, according to Mr. Mactear, contains a variety of sulphides of calcium, but in combination with excess of sulphur and sulphuretted hydrogen, and there is in it little or no hyposulphite. As it oozes from the ancient waste heaps it is collected by an appropriate arrangement in an underground tank, from which it is pumped up as required into a reservoir at the works.

The theory of Mr. Mactear's process is this:—The liquor to be treated contains sulphide, and perhaps some hyposulphite of calcium. When hydrochloric acid is added, both these salts are decomposed. In the decomposition of the hyposulphite, sulphur is thrown down and sulphurous acid is set free; in the decomposition of the sulphide sulphuretted hydrogen is set free. The sulphuretted hydrogen is decomposed by the sulphurous acid, the sulphur in both being set free, the oxygen of the sulphurous acid and the hydrogen of the sulphuretted hydrogen uniting to form water. When there is not sufficient hyposulphite present to supply the requisite quantity of sulphurous acid, the latter is specially prepared. The sulphurous acid is in that case prepared from pyrites, and is conducted for absorption from the burners to a tall wooden tower containing coke, down which water is made to trickle. The hydrochloric acid used is also specially made of the strength of 22° (Twaddle). A large wooden vat, like a brewer's vat, is provided for the decomposition, and into this are run at one and the same time, in quantities duly proportioned to the strength of the liquor in use, the liquor, the hydrochloric acid, and the sulphurous acid, the last somewhat in excess. The whole contents of the vat are then stirred together by a mechanical agitator, and steam is thrown in to raise the temperature to about 145° Fahr. When the decomposition is complete the contents of the vat are run off into deposit tanks, where most of the sulphur deposits. The sulphur sludge is then washed with cold water, and in order to detain the fine particles of sulphur which run off with the washing water, the washings are made to run slowly along a zig-zag wooden trough, where these fine particles deposit. The process is conducted without nuisance; the warm vapour that rises only smells a little of sulphurous acid or sulphuretted hydrogen, but not sufficiently to cause offence. This was the proceeding which I saw in operation at St. Rollox, when I paid my first visit in 1876. At a recent visit I found that the process of recovery of sulphur was being applied to the actual substance of the old waste heaps, which were being dug down for the purpose. The part of the heap that is used is the grey-coloured part, which consists principally of sulphite of lime, a salt which is soluble in sulphurous acid. The material is first ground down with water or yellow liquor in a pug mill, and then the water holding the sulphite in suspension is treated in the vats in a similar way to the liquor, sulphurous acid from the burning of refuse sulphur (part of the final product of the operations) being first introduced to dissolve the sulphite, and then hydrochloric acid. Mr. Mactear says that fresh waste may be treated in the same way.

Composition of tank waste liquor.

Mr. Mactear has been good enough to give me the following average composition of the waste heap liquor at St. Rollox, and of the oxidised or mixed liquors now used there in the decomposers (excluding sulphate of lime).

A.—In liquor draining from waste heaps, the sulphur exists as follows:—

	100 parts of sulphur.	Vol. per cent. in liquor at 13 deg. Tw.
$Ca S H_2S$	76·3	3·15
$Ca S_2 O_3$	18·2	·75
$Ca S_2 + S_x$	5·5	·23
	100·0	4·13

B.—In oxidised or mixed liquor, as used in the decomposer:—

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	100 parts of sulphur.	Vol. per cent. in liquor at 22 deg. Tw.
$CaS\,H_2S$	29·6	1·60
CaS_2O_3	44·4	2·40
$CaS_2 + S_x$	20·0	1·40
	100·0	5·40

The second columns mean, that in 100 grains water measure of the liquors so many grains of sulphur exist in the several forms of combination. The volume per cent. will vary with the sp. gr., the proportions to the 100 of sulphur remaining constant.

Prior to the discovery of this process, Mr. Mactear says in his evidence before the Noxious Vapours Commission (6417), that they tried Mond's process, but gave it up for two reasons, viz., first that they "could not use up all the yellow liquor," and secondly, because "it gave considerable quantities of sulphuretted hydrogen while the air was being forced through the waste in the oxidizing process," and this gave rise to complaints from the Medical Officer of Health. Prior to that, all the liquor ran by the Pinkston Burn and River Kelvin into the Clyde, and was a great source of nuisance. At the present time the only occasion on which liquor is run off (and then by a pipe specially laid for the purpose) into the Clyde is when heavy floods have washed the heaps, and made a liquor too dilute to be utilized by the new process. Mr. Mactear informed me on the occasion of my last visit that no liquor whatever had been run away for a period of 18 months.

Prevention of nuisance at the Tyne Alkali Works.

I have yet to mention a means of abating the waste-heap nuisance (or rather that from the yellow liquor), which I observed in operation at the Tyne Alkali Works, in the town of South Shields. At one time the liquor from the old waste heaps used to drain off into the town sewers, and created a nuisance along the whole line of them, the ordinary water traps in domestic use being altogether incapable of arresting the smell of sulphuretted hydrogen. At about the beginning of 1876, Dr. Lunge, who was then the manager of these works, established experimentally a process of deodorisation by means of the refuse from the Weldon "settlers;" and the result was such a deodorisation of the liquors, that they are now run harmlessly into the sewers.

The liquor from the waste heaps, beneath which are some springs, is collected in wells, from which it is raised from time to time by pumping, or by means of a pulsometer, to a rough wooden channel, along which it is conducted to a shallow excavation in the earth, so as to form a sort of pond. In the course of its flow along the channel it receives through another similar channel the refuse sedimentary matters from the "settler" of the Weldon plant (p. 228); and, inasmuch as the sediment is not washed at these works, the watery part of what is discharged from the "settler" contains a notable proportion of proto-chloride of manganese. Arrived at the pond, a mud becomes deposited there, and the liquid supernatant portion is allowed to flow away into a succession of four similar ponds, in the second of which mud from the first pond is stirred up with the liquid so as to promote oxidation. From the last pond the liquid matters run off clear and odourless into the public sewer. The deodorisation, partially effected on the mixture of the two liquors and completed in the ponds, is accompanied by a deposition of sulphur, and the proportion of sulphur is found to increase in the deposited mud as the deodorisation proceeds in pond after pond. Mr. C. Tookey, who

has been studying this subject for me, found that whereas the mud first deposited contained only 2 per cent. of sulphur, that deposited in the later ponds contained as much as 6·7 per cent. There are two substances in the "settler" refuse which have the power of decomposing polysulphide of calcium with deposition of sulphur, namely, proto-chloride of manganese and hydrated peroxide of iron. The former of these being in solution must decompose its equivalent of sulphide of calcium immediately on admixture with the yellow liquor, with the formation of proto-sulphide of manganese and chloride of calcium. The latter would act less speedily, but with the formation of sulphide of iron and lime, which last would speedily fall as carbonate of lime, by absorbing carbonic acid from the air. Mr. Tookey found that the mud which he examined effervesced with evolution of carbonic acid on the addition of hydrochloric acid to it. Now both the substances formed by the decomposition taking place in the channel and first pond, namely, the proto-sulphide of manganese and the sulphide of iron, are capable of absorbing oxygen from the atmosphere, the former with conversion partly into what has been termed hydrated proto-sesquioxide of manganese and partly into sulphate of manganese, and the latter with conversion again into hydrated peroxide; and probably the effect of exposure in the open ponds and of the stirring up is to facilitate this conversion. But since chloride of calcium is present in the liquors, it is probable that a double decomposition takes place as quickly as sulphate of manganese is formed, with the re-formation of an equivalent quantity of chloride of manganese and precipitation of sulphate of lime. Chloride of manganese, oxide of manganese, and peroxide of iron thus formed would decompose fresh quantities of polysulphide of calcium; and so the process probably goes on, both the manganese compounds and the peroxide of iron working "round and round," as carriers of oxygen merely, so long as there is any sulphate to be acted on, until the final pond is reached, from which the clear liquor runs off into the sewer. As this process of deodorisation is effected at present, there is some offensive odour of sulphuretted hydrogen from the first pond, the cause of which is the action of the acids present in the air and rain upon the sulphide of calcium, which the quantity of chloride of manganese added is not sufficient to decompose at once. The effluent liquor tastes decidedly styptic, and Mr. Tookey, when he examined it in the summer, found it to contain in solution in each imperial gallon :—

Protochloride of manganese	- -	764·58 grs.
Chloride of calcium	- - -	2176·15 „
Sulphate of lime	- - - -	223·72 „

and chlorides of magnesium and sodium in addition. He further tells me, that in the muds from the first and later ponds that he examined at the same time, he found no notable quantity of peroxide of manganese, and that they did not evolve sulphuretted hydrogen when treated with hydrochloric acid. Examining again in the cold weather of November, he found the effluent liquor only to contain 223·66 grains of protochloride of manganese in the gallon. Both muds (the first mud being black) also evolved sulphuretted hydrogen on addition of hydrochloric acid; but that from the first pond more than that from the later ponds. The oxidation (revivification) had evidently been less perfect than it was in the summer. It would appear that, both in summer and winter, much deodorising material (soluble salt of manganese) is, in the present rough method of working, run away to waste into the sewers. It would also appear further that the process has in it capabilities of efficient and economical working, if it were carried out systematically, and with more appropriate plant.

THE MANUFACTURE OF BLEACHING POWDER.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 29, 1876	Gamble and Son -	St. Helens, Lancashire.	Manufacture of alkali and sulphuric acid.
,, ,, ,,	Bridgewater Chemical Works.	Ditto - -	Ditto, ditto.
,, 24, ,,	Squire & Co. -	Victoria Docks -	Ditto, ditto.
May 18, ,,	Sullivan & Co. -	Widnes - -	Ditto, ditto.
,, ,, ,,	Gaskell, Deacon, & Co.	Ditto - -	Ditto, ditto.
,, ,, ,,	Atlas Works -	Ditto - -	Ditto, ditto.
Dec. 5, ,,	St. Rollox Chemical Works.	Glasgow - -	Ditto, ditto.
,, 6, ,,	Charles Tennant & Co.	Hebburn - -	Ditto, ditto.
Mar. 22, 1877	Tyne Alkali Works	South Shields -	Ditto, ditto, and chlorate of potash.
,, 23, ,,	Richardson -	Jarrow - -	Ditto, ditto.
May 15, ,,	Golding, Davis, & Co.	Widnes - -	Ditto, ditto.
,, ,, ,,	James Muspratt and Sons.	Ditto - -	Ditto, ditto, and recovery of sulphur from waste.
Mar. 14, 1878	Richard Bealey & Co.	Radcliffe, Manchester.	Ditto, ditto, and bleaching.
April 2, 1879	Hunt Brothers -	Castleford -	Ditto, ditto.
May 15, ,,	Muspratt Brothers and Huntley.	Flint - -	Ditto, ditto, and wet process of reduction of copper.

Process of manufacture.

"Bleaching powder," known also popularly under the term "chloride of lime," is, when newly prepared, a mixture of hypochlorite of lime (Ca O, Cl O) with chloride of calcium, together with some free hydrate of lime and a trace of chlorate of lime. It is made by exposing hydrate of lime (slaked lime) in a closed chamber to the action of dry chlorine gas. Four modes of preparing chlorine are in use in this country:—

1. Ordinary process.

1. In the ordinary old process, a "still," as it is termed, is used for the manufacture of the chlorine by the action of hydrochloric acid, condensed in the strong acid condensers of the alkali works (to which this manufacture is appended), on black oxide of manganese ($Mn\ O_2$). The still consists of a square chamber of siliceous stone (usually Yorkshire flag), usually four sided, 4 or 5 feet wide and about 3 feet deep; the thick stones of which it is made being secured together both by an appropriate cement and by strong iron bolts. The still has a man-hole with proper close cover above for introducing the charge of manganese, upon which the acid is poured in. There is a pipe with tap below for running off the spent material. Steam is thrown into the chamber to raise its temperature towards the end of the process. The chlorine thus generated is conducted by stoneware pipes, the sections of which are closely luted together, to the bleaching-powder chambers. These are large chambers made of lead or stone, of a size varying with the requirements of the establishment, but commonly measuring 60 feet long by 30 feet wide, and of a height just sufficient for a man to stand in. The floor upon which the lime is laid is flat, and there are doors which are open only during charging and discharging, and when the charge requires to be manipulated. On opposite sides there are glass peep-holes,

by which the amount of unabsorbed chlorine in the chamber can be judged of from its colour. When there are several such chambers, they are made to communicate by means of a pipe, the chlorine being then conducted through the series of chambers, commencing with that chamber in which the powder is most advanced, and ending with that in which it is least advanced. The hydrate of lime, carefully prepared, is laid upon the floor to a depth of about 6 inches, and ridged by means of a rake, so as to increase the exposed surface, and the chamber being closely sealed, the gas is allowed to enter for about 48 hours. The doors are then opened to allow of the powder being turned, and then the gas is passed in for another 48 hours. In order to cause absorption of as much as possible of the chlorine in a chamber, before opening the doors for either turning the powder or discharging the chamber, it is customary to shut off the gas for about 12 hours. Some manufacturers say that before discharging a chamber they shut off the gas for 48 hours. The practice seems to vary. The doors being then opened, they are left open for a sufficient length of time for the atmosphere within to become so far diluted with common air as to permit of the entrance of the workmen. In some works casks for the "packing" of the powder are then rolled in, and the workmen, with their mouths and noses muffled up, shovel the powder into the casks. In other works there are openings in the floor (closed at other times) through which the powder is discharged by a wooden shoot into the casks placed beneath. The residue in the chlorine still is a strong acid chloride of manganese, which when run off so as to come into relation with tank-waste liquor may become a source of nuisance.

2. "Weldon" process.

2. The "Weldon or regenerative process" for preparing chlorine saves this loss of manganese, by recovering the manganese as peroxide and using it again in the form of "manganese mud." The spent material is run off from the still into a well, called the "neutralising well," where limestone is added, which neutralises the free acid, forming chloride of calcium, while iron and alumina, from the chloride of iron and alumina present, are thrown down as peroxide of iron and alumina. The neutral solution now contains protochloride of manganese and chloride of calcium, and holds in suspension oxide of iron, alumina, carbonate of lime and sulphate of lime, which suspended matters are allowed to settle in "settlers," into which the turbid solution is pumped.

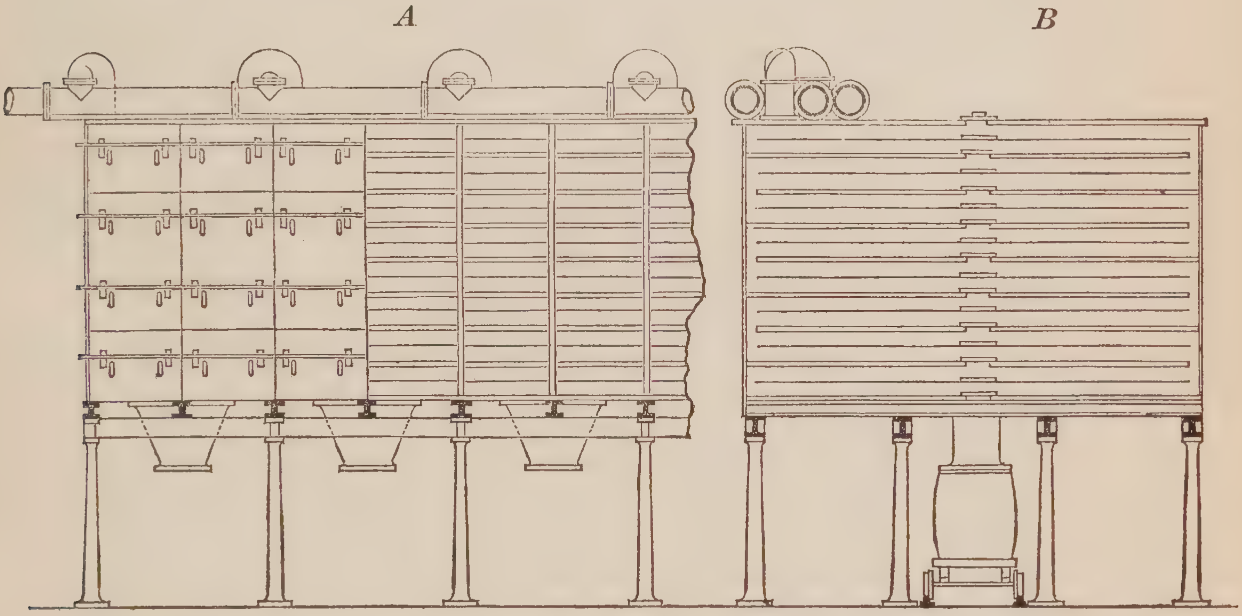
The clear solution is then transferred to a deep iron cylinder called the "oxidiser," into which milk of lime is gradually run, which throws down protoxide of manganese; steam is thrown in to raise the temperature to about 140° Fahr., and air is blown in by a blower. The effect of this is to peroxidise the manganese, which settles in the form of a thin black mud in the vessels or "mud settlers," into which the contents of the cylinder are, after about four hours' blowing, run off. In order to avoid loss of manganese, the deposit in the first "settlers" is washed, and the washings are added to the liquor in the oxidiser. Some manganese chloride, however, which it is not worth while to remove. still remains in the deposit. The peculiarity of the Weldon process lies in this recovery, and in the use of the mud instead of fresh manganese for making chlorine. It is used in the form of mud. The still employed is usually of octagonal form, and is made of slabs of siliceous stone carefully cemented and bolted together. The hydrochloric acid to be decomposed is first run into the still, and upon this the mud is run in gradually, so as to cause the chlorine to come off in as uniform a manner as possible. The residue in the still is run off into the neutralising well as before.

. "Deacon" process.

3. In the "Deacon process" the use of peroxide of manganese is dispensed with, and the hydrochloric acid is used, not in a state of

solution, but of gas, which is decomposed by passing it at a high temperature over bricks or similar material saturated with a solution of a salt of copper, the sulphate being the salt usually employed. The hydrochloric acid is always that generated in the salt-cake manufacture. First, mixed with air, it is heated by passing it through heated iron tubes, from which it is conducted through a series of cylinders (the arrangement of which may be variously modified) containing the saturated bricks or other material. In the presence of the copper salt, which itself undergoes no change, the hydrochloric acid is decomposed by the oxygen of the air, chlorine is liberated, and the hydrogen is converted into water; so that what leaves the apparatus is chlorine, water, oxygen, nitrogen, and so much of the hydrochloric acid as has escaped decomposition. To remove this acid the gaseous mixture is first passed through water, and then, to dry it, through a coke tower down which sulphuric acid is run; and, being thus freed from acid and water, the chlorine, although dilute, is sufficiently pure for making bleaching powder. The apparatus used for saturating the lime is modified to meet the special requirements of the process. The drawing, Fig. 31, for which I am indebted to

Fig. 31.



Messrs. Gaskell and Deacon, illustrates its construction A in elevation and part in longitudinal section, and B in transverse section. It consists of a long chamber divided into sections by vertical partitions, with communications to enable the chlorine gas to pass from one section to another in any way that may be desired. Each pair of vertical sections is virtually a chamber of itself, so arranged that the gas passing in at the top of one part enters the next section of the pair at the bottom, and from this passes into a pipe above, which conducts it to another pair of sections. Each section is provided with shelves springing alternately from the opposite sides as shown in B. In each section the lime is introduced at the top, and falls through a hole in each shelf or tray to the bottom. The lower shelves are first charged, and, as each is charged, the hole in the shelf above is covered with a cover or plate, and so on to the top, a rake being used to spread the lime on each shelf. The rake is worked from the outside through openings in each section, which, when the gas is passing, are closed by plates cemented on. The gas is passed through the several sections in such order as to expose to its action first such lime as is most advanced towards saturation, and lastly newly introduced lime. The discharging of each section is similarly effected through a hole at

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On Effluvium Nuisances, by Dr. Ballard.

the bottom of the section, beneath which hole the cask is placed, a funnel of sacking being interposed to direct the powder into the cask and to prevent the diffusion of dust. Both this arrangement and the hole with its little cover in the middle of each shelf are shown in B. The gas is drawn through the whole of the apparatus by means of a Root's or other form of blower. When examining this apparatus at Gaskell and Deacon's works I could detect no odour of chlorine in the issuing gases. Evidently it had all been taken up.

4. "Dunlop" process.

4. At St. Rollox I saw another process in use for making chlorine, namely, "Dunlop's process." It is used there only for a part of the work. There was a series of six iron cylinders laid horizontally, and each heated by a moderate fire beneath. Each cylinder was about 7 feet long and 5 feet wide. Into these cylinders are introduced salt, nitrate of soda, and sulphuric acid. The reaction continues for about 48 hours, and the result of it is a mixture of gases, viz., nitrous acid (NO_3), nitric acid, chlorine, and a little hydrochloric acid. This mixture of gases is conducted through a series of large leaden bottles like Woulffe bottles, containing strong sulphuric acid. This absorbs the nitrous and nitric acids, and the chlorine and hydrochloric acid pass on to a wash-tower where the latter is arrested, while the chlorine is conducted to the bleaching-powder chambers. The residue in the cylinders is sulphate of soda, which is run off by a wooden channel in the form of a mud, and conducted to a salt-cake pan where, a little more salt being added to take up the excess of sulphuric acid, it is converted into salt-cake in the ordinary way.

Nuisance.

No one can walk through the department of an alkali work in which chloride of lime is being made by the ordinary process without perceiving, more or less unpleasantly, a generally-diffused odour of chlorine, which proceeds from various unavoidable causes, such as accidental leakages. I have never traced nuisance outside works to this cause alone. The only nuisance from bleaching-powder making which I have heard complained of arises when the chambers have been opened for turning over the lime or for the discharge of the powder from them. The odour of chlorine, when diffused in considerable proportion in the air, is distinctive and suffocating, but when the proportion is small, as when the chlorine has passed through the air for a long distance (say some miles), becoming diluted by diffusion, is less distinctive, and is apt to be confounded by unpractised persons with the odour of hydrochloric acid, with which, moreover, under ordinary circumstances, it is more or less mixed in the air. Part of the nuisance in the immediate vicinity of the chambers may be due to dust of chloride of lime blown out by the wind while it is being packed. The men who enter the chambers to pack the powder are apt to suffer from the inhalation of the gas and dust to which they are exposed, sometimes after a concentrated dose acutely, when they are said to be "gassed," but ordinarily less acutely, their sufferings consisting in a liability to cough and bronchial irritation, repeated attacks of which are believed by medical men practising among them to lead sometimes to emphysema and other structural changes in the pulmonary organs. Mixed with other gases, as the fumes from this process are when they are diffused in the air outside works, it is not practicable to distinguish between the evil effects which they occasion and those attributable to the other gases, such as hydrochloric acid, with which they are mingled (see p. 206).

Prevention of nuisance.

So far as I have been able to learn or to observe, the Deacon process is not productive of any nuisance outside the works. When it is duly worked, the draught is at all times from the outside into the interior of the apparatus, and a thorough absorption of the chlorine

made is provided for. In addition, the mode of packing is such as to obviate as far as practicable the diffusion of dust. The desideratum is to so arrange the process of making in ordinary chambers as that it shall be equally innocuous. The objects to be attained are, 1st, such a removal of chlorine from the atmosphere of the chamber as shall suffice to prevent nuisance when the doors are opened to allowed of the entrance of the workmen; and, 2ndly, some contrivance to prevent the escape of dust into the external atmosphere during the packing.

The methods of attaining the first of these objects that I have seen in use are the following: A door in the chamber about to be discharged is slightly opened, and, either by means of a fan or by means of the chimney draught, the atmosphere of the chamber is drawn off into another chamber containing fresh lime which absorbs the chlorine; and this process is allowed to go on for three or four hours, or until the free chlorine is all absorbed. Another plan is to divide the chamber floor by a low ridge or division into two parts, which are discharged and charged with fresh lime alternately, one part being discharged and recharged when the lime on the other part is only partially converted into chloride. The effect of this is that during, say, the 12 hours that the gas is shut off prior to discharge, the partially converted lime absorbs a good deal of the chlorine present in the chamber, which is not opened until the colour of its atmosphere indicates that most of the chlorine has been thus absorbed. But in neither of these ways is the nuisance entirely done away with, although it may be considerably reduced by the use of either of them. Mr. Glover informs me that his practice is to scatter in through a man-hole in the top of the chamber a sufficient small quantity of quite freshly-prepared hydrate of lime in such a way as to make the atmosphere of the chamber dusty with the lime. This dust, he says, absorbs any free and unappropriated chlorine present. The main difficulty, as I understand it, lies in the instability of the compound manufactured. In order to meet the requirements of the trade, bleaching powder must contain 35 per cent. of chlorine at least; and the last per-centages are not only introduced with difficulty, but are speedily given off again when the powder is exposed to the action of the air. And there is another difficulty due to the retention of chlorine mechanically in the powder as it lies upon the floor, which chlorine is liberated into the atmosphere as soon as the powder is disturbed for packing. Mr. Glover tells me, as the result of his long experience, that this mechanical retention of chlorine occurs to a serious extent only when the process is hurried, and that when the process is not improperly hurried, powder at 35 per cent. contains enough free lime to absorb the whole of the chlorine in contact with it. Many manufacturers, for reasons sufficiently cogent, prefer the old-fashioned process to the Deacon process, in which a weaker gas is used; and this being the case, it must be left to future ingenuity to devise a method more effectual than those methods I have described for obviating the accompanying nuisance.

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Establishments visited.

THE MANUFACTURE OF GLASS.

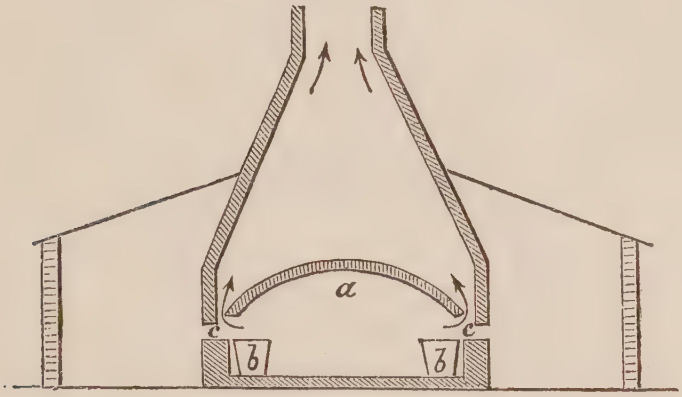
Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 11, 1876	Cartwright -	Warrington.	—
„ 16, „	Robinson, Son, and Skinner.	Ditto.	—
„ 17, „	Borron - -	Newton.	—
June 3, 1878	Jenkinson -	Edinburgh.	—
„ „ „	Ford - -	Ditto.	—
Feb. 25, 1879	Lyon - -	St. Helens, Lancashire.	—
„ 26, „	Cannington and Shaw.	Ditto.	—
„ „ „	Ravenshead Plate-glass Works.	Ditto - -	Preparation of ochre.
„ „ „	Sutton Plate-glass Works.	Ditto - -	Ditto.
„ 27, „	Pilkington -	Ditto - -	Ditto.
April 2, „	Albion Glass Bottle Works.	Castleford.	—
„ „ „	E. Breffit - -	Ditto.	—
„ „ „	Rogers - -	Ditto.	—
July 1, „ -	Tyne Plate-glass Works.	South Shields -	Preparation of ochre.
„ „ „ -	South Shields Bottle Works.	Ditto.	—

Glass is an insoluble mixture of silicates, produced by the fusion together of materials, the precise nature and proportions of which vary with the kind of glass to be made, and to some extent also in different works making the same kind of glass. It will suffice, for the purpose of this Report, to describe briefly the process of the manufacture of bottle glass, plate glass, and flint glass, since these three will sufficiently illustrate all it is necessary for me to say. *Bottle glass* is made of the cheapest materials that will answer the purpose of making a coloured common glass; they are sand, lime (sometimes refuse lime from gasworks), red clay, salt cake (sulphate of soda) or common salt, or both, and broken glass, known in the trade as "cullet." To these some oxide of manganese or arsenious acid is commonly added. In making *plate glass* and the several varieties of window glass, the materials are more carefully selected; the sand and lime used are of a better quality and no clay is used, nor any common salt, and the broken glass (if used) is glass of the same quality as that about to be made. Some charcoal is also added to the mixture for plate glass. *Flint glass* is similarly made of carefully selected materials, namely, from Rouen sand, soda ash or carbonate of potash, and red lead instead of lime. Arsenious acid is usually added to the mixture, both for plate and flint glass. The materials are commonly melted together in large circular fire-clay pots. Those used for bottle or plate glass are open at the top, but those used for flint glass are domed over, and on one side of the domed top have an opening with a very short neck through which the materials are introduced and the glass, when made, manipulated. These pots are arranged in a low domed chamber or "cave," into and through which the flame and heated air, with products of combustion from the furnaces, are made to pass. In the sides or at the ends or round the circumference of this chamber or "cave" there are openings through which the materials are intro-

duced into the pots, and the glass is taken out of them for manipulation. In the case of plate glass the pot containing the finished glass is removed bodily from the chamber and conveyed to another part of the building for the manufacture of the plate, and doors, closed during the melting process, are provided to allow of such removal; but in the manufacture of other kinds of glass the pots once put in are not removed until they are worn out. The use of tanks instead of pots for the manufacture of bottle glass is now becoming common in large works. Fig. 32 is a rough diagram which

Fig. 32.

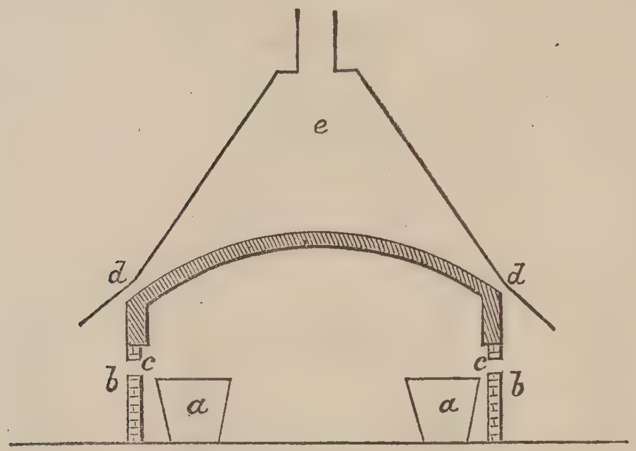


shows the ordinary arrangement of a bottle glass furnace, *a* representing the arch of the cave, *b* the open pots arranged round the interior, and *c* the working opening opposite each pot. The fireplaces are so arranged at opposite sides that the heated air and products of combustion fill the cave and sweep the surface of the materials in the pots on their way to discharge through the working openings of the chamber, and, in the course of the arrows, into the conical chimney. In their course they carry mixed with them the gases eliminated during the melting of the materials. When sulphate of soda is used as the source of the alkali, the silica acting on the sulphate at a high temperature causes the evolution of sulphuric acid, but, when salt is used, the acid evolved in the reaction is hydrochloric acid. When a tank, heated by ordinary fires, is used instead of pots, the only difference is that the space which would otherwise have been occupied with pots is converted into a tank constructed of fire-clay bricks or thick tiles; such a tank may be about 15 feet 6 inches long by 9 feet 6 inches wide and 17 inches deep. At some large works the Siemens regenerative furnace is used for the purpose of heating the tank with gas. In this case the tank is elongated, and is made circular at one end, where alone the working openings are placed. At Canningson and Shaw's works the tank used is 30 feet long by 11 feet 6 inches wide, and the chamber is 5 feet 6 inches high. The circular working part of the tank from which the glass is taken is divided from the major part by a fireclay partition or bridge. At the other end, just above the tank, is a feeding opening into which the materials are fed as they are required: the melted glass passes through openings in the lower part of the bridge to the working part of the tank. The ignited gas is introduced by several gas channels just above the tank, and, passing across and over the contents of the tank, escapes by similar openings on the other side. At due intervals the current is reversed. The products of combustion mixed with the gases evolved from the tank escape together, after passing through the regenerator, from chimneys 100 feet or 120 feet high.

It is important to observe that, where fires are used either with a tank or with pots, the materials are only charged in to make the glass for the next working about 12 or 13 hours before the glass is wanted, say about

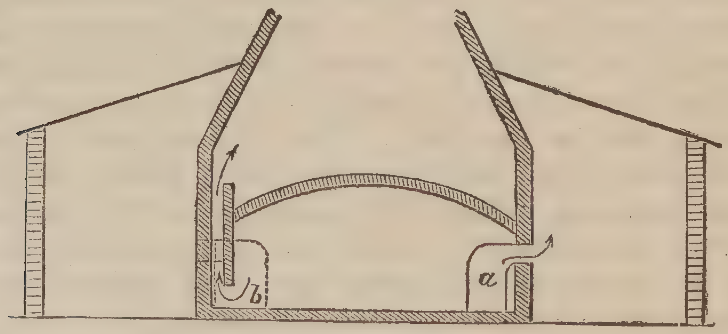
4 or 5 o'clock in the evening; but, where the elongated tank with gas-heating is used, the charging is going on constantly at the one end as the glass is taken out at the other or working end; no particular time is kept, but materials are put in as they are wanted to keep up the supply of glass. At the plate glass works at St. Helens, the large open pots *a* are placed in a chamber (of which Fig. 33 is a rough diagram) about

Fig. 33.



10 feet high, heated either by gas on the Siemens principle or by fires, in which latter case the products of combustion and the gases evolved pass away together by a flue in the middle of the floor. Opposite each pot is a door *b* constructed of fire-brick, which is only opened to remove or replace a pot, and in the door near its upper part is an opening *c* capable of being closed, through which the materials are thrown into a pot, or through which the interior of the chamber may be inspected. In order to catch any gases that may escape by this opening, as for instance when a door is opened, an iron hood *d* projects over each door, and conveys the gases away into an inclosed space or chamber *e* above, and thence by pipes through the roof of the building in which the furnaces are erected. Mr. W. W. Pilkington informs me that the chief issue of gas from the reactions within the pot occurs shortly, say for about a quarter of an hour, after charging. In about two hours after a pot has been charged the materials are found to have sunk down in it, and then more material is charged in, and so on as often as may be necessary to fill the pot with glass. The pots are charged in the evening for work the next day. For making *flint* glass domed pots *a* are used, as has been already mentioned, and they are set, as shown in the rough diagram Fig. 34, in such a way that

Fig. 34.



the opening in the upper part corresponds with the working opening. The heated air from the fires plays round and over these pots, but does not enter them; but the products of combustion escape from the cave

To face Page 235.

FRISBIE'S PATENT FEEDER, AS AFFIXED TO GLASS FURNACES.

Fig. 1.

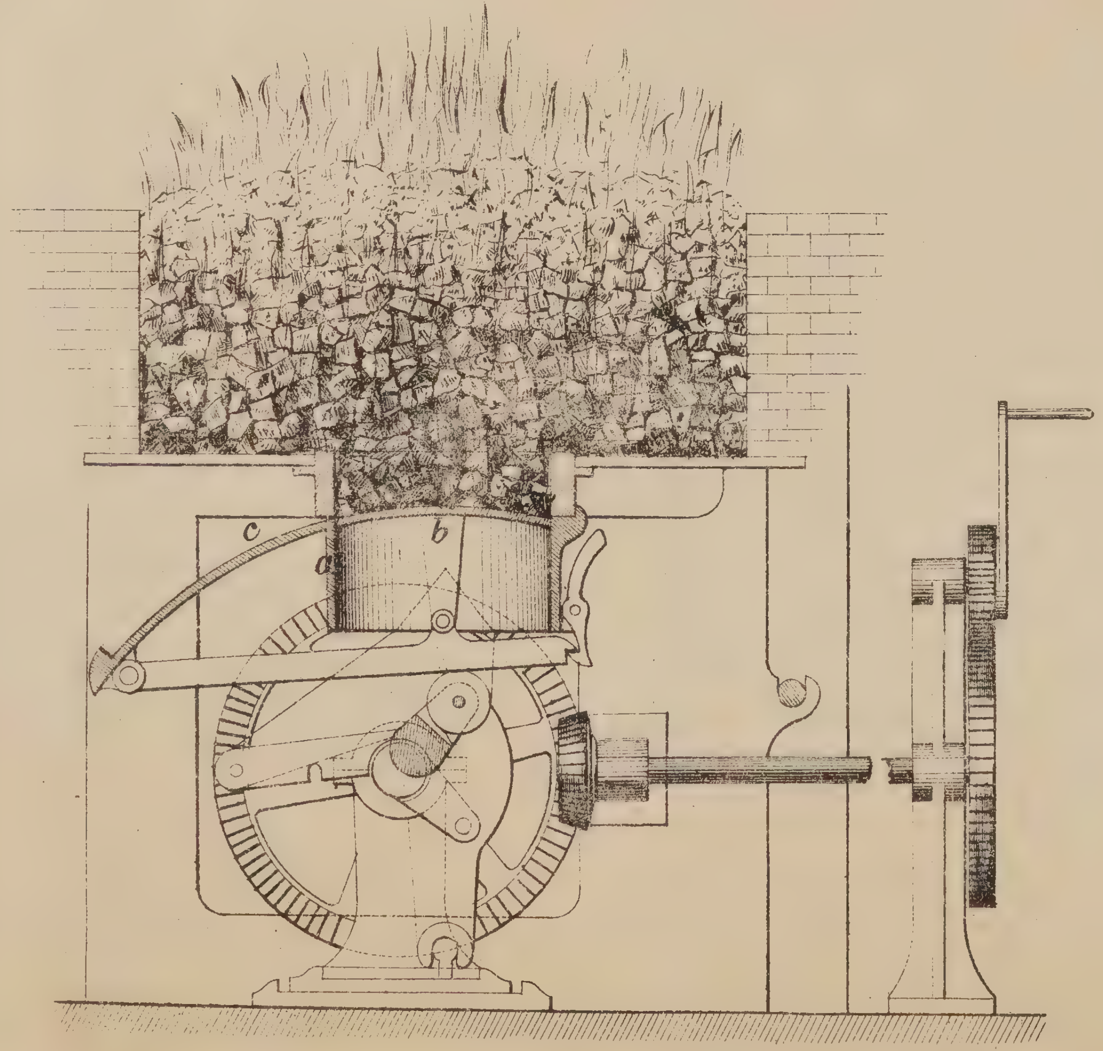
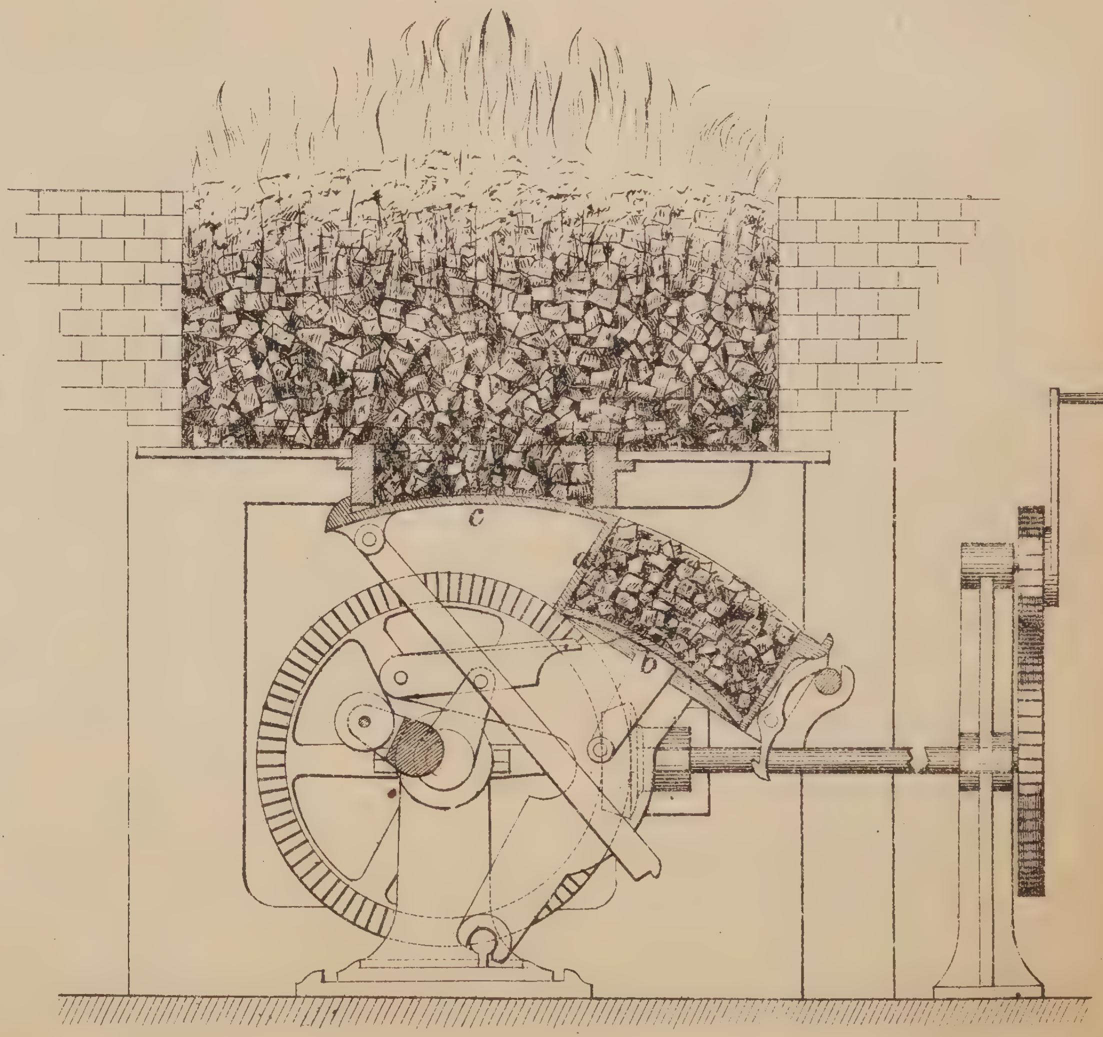


Fig. 2.



DANGERFIELD. LITH. 22. BEDFORD S^T. COVENT GARDEN.

Nuisance.

by a chimney opening *b* at the side of each pot near the floor, and so, as indicated by the arrows, into the conical chimney. The gases liberated during the reactions within the pot pass out into the building in which the furnaces are erected, and do not mix with the products of combustion.

The two sources of annoyance from glass making are the discharge of smoke from the low chimneys of the glass-houses, and the evolution of acid fumes from the decomposition of the sulphate or chloride of sodium used in the manufacture. So far as mere offensiveness is concerned, the smoke is the greater nuisance of the two; and the most that can be said of the evolution of acid, apart from its evil influence upon vegetation, appears to me to be that it adds its contribution to the pollution of the atmosphere of such places as St. Helens or Castleford, where other works emitting acid fumes into the atmosphere are also in operation. The extent of this contribution may be roughly estimated from the fact stated before the Noxious Vapours Commission, that at the plate-glass works in St. Helens alone 198 tons of sulphate of soda are decomposed weekly. At the largest bottle works at St. Helens (Canningson and Shaw) 15 tons of sulphate of soda are, as I was informed, used weekly.

Of these nuisances only one, namely, that of smoke discharged at a low level, applies to flint glass making, since carbonates are alone used as sources of alkali.

Prevention of nuisance.

A good deal has been done in several places to do away with the smoke nuisance from glass works. The Siemens gas furnace is one of the contrivances the application of which to the largest bottle and plate glass works in the kingdom has had an effect of this kind, and its use appears to be extending. Another valuable contrivance for the prevention of smoke, which I have seen in very successful operation at several bottle and flint glass works, is Frisbie's mechanical fire-feeder and grate, a description of which is given by Mr. B. P. Walker in the Proceedings of the Meeting of the Institution of Mechanical Engineers at Birmingham in 1876. Its object is to supply the fuel at the lower instead of at the upper surface of the fire, and in this respect the principle of it is not new. The grate is provided with a central aperture, through which the fuel is thrust up. The fuel is fed into a cylindrical box or hopper *a*, which, swinging on pivots, is provided with a movable bottom or piston *b*; the grate aperture being meanwhile closed by a curved plate or apron *c* attached to the margin of the box which retains the fuel in the grate. When full, the box is swung directly beneath the aperture in the fire-grate, and then by a mechanical arrangement which need not be described here, the piston bottom of the box rises and pushes the fuel into the fire. By reversing the movement the box is swung back again, the bottom still supporting, partially, the coals, until the supporting action of the apron is fully brought into play, and the box is altogether withdrawn from beneath the aperture, when the bottom falls, and the box is ready to receive a further charge. Plate XXVI. shows the apparatus in longitudinal section; Fig. 1 when the charge has been thrust in, and Fig. 2 when the box is newly filled, ready for use, the charge being supported by the curtain. It is conveniently applied in the centre of the floor of a flint glass furnace at Jenkinson's works, in Edinburgh; and I saw preparations for its use in the centre of a tank at some bottle works at St. Helens; otherwise it is used in the ordinary position of the fireplaces.

The evolution of acid fumes, other than would result from the combustion of fuel, would not of course occur were not sulphate or chloride used as a source of alkali; but sulphate and chloride are used in all but flint glass making, because they are cheaper than alkaline carbonate and

answer the requirements of the manufacturer equally well. It is said that the necessity for their use has arisen out of foreign competition in the trade, and is maintained by it. A return to the use of carbonate being thus impracticable, the question has of course arisen whether the acid evolved might not be arrested before its escape into the external air. But the difficulty of doing this has been obvious to all persons who have considered the subject: it arises (as a similar difficulty has arisen in respect of some other trades) mainly out of the high temperature at which the fumes reach the chimney. No way of overcoming the difficulty has yet been devised. The object to be sought appears to be the cooling of the evolved gases sufficiently to allow of their being effectually condensed, a result which must somehow be attained without undue interference with the draught of the furnaces. This object could be attained readily enough if the gases evolved from the pots could be kept separate from the products of combustion of the fuel. In the case of flint glass making (where no strong acid gas is evolved) this is done by doming the pots, and it is practicable on account of the comparatively low melting point of the flint glass mixture. But the manufacturers tell me that no muffle arrangement would allow of the application of the amount of heat required to melt the less fusible glasses, and that the hot air from the fires must therefore be permitted to come in contact with the metal in open pots or tanks. It appears to me that this is a proper matter for experiment.

Preparation of ochre.

Preparation of Ochre.—At the plate-glass works which I have visited I found that the ochre used for polishing the plates was made upon the premises. The material used for making it is crystallised sulphate of iron, which, when exposed to sufficient heat, gives off first the greater part of its water of crystallisation and then monohydrated sulphuric acid. The heating is effected either in a reverberatory furnace having a flat floor on which the sulphate is spread out, or in a muffle furnace. The quantity calcined at one operation is about 5 cwt. and the calcination is completed in about eight hours. The material is rabbled from time to time through doors in the side of the furnace which are opened for the purpose. The muffle furnaces have also other openings specially provided for the admission of air requisite for the peroxidising of the iron. Mr. W. W. Pilkington informs me that the quantity of copperas calcined at their works is about 25 cwt. per week, and that 10 tons of coal are used in the calcination of this quantity in a muffle furnace. The acid vapours evolved are conducted by a flue into a chimney about 200 feet high with which the fire-flues also communicate. At the Ravenshead Plate-glass Works the quantity of copperas calcined (muffle furnaces being used) is said to be about 3 tons per week. At the Sutton Plate-glass Works, belonging to the same firm, where a reverberatory furnace is used, I was informed that 10 cwt. of copperas were used at each charge, and that altogether about 50 cwt. of it were calcined each week. There is no suggestion of difficulty in condensing the acid fumes from the process, nor, inasmuch as the process is equally well carried out in a muffle as in an open furnace, can I see that there could be any.

THE CALCINATION OF IRONSTONE AND TAP-CINDER. —IGNITION OF WASTE-HEAPS OF IRON WORKS.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

Establishments visited.

ESTABLISHMENTS VISITED.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Oct. 20, 1877 -	Chatterley Iron Works.	Tunstall - -	Smelting of iron.
May 24, 1878	Tees Iron Works -	Middlesborough -	Smelting of iron ore.
Jan. 9, 1879 -	Dowlais Iron Works	Dowlais - -	Ditto, and coking.
„ 15, „ -	Blaenavon Iron Works.	Blaenavon, S. Wales	Ditto, ditto.
„ 22, „ -	Pearson - -	Windmill End, Dudley.	Ditto, ditto.
Mar. 4, „ -	Lord Granville -	Hanley - -	Smelting of iron.
„ „ „ -	Shelton Bar Iron Company.	Ditto - -	Ditto.
„ 5, „ -	Stanier & Co. -	Silverdale, Staffordshire.	Ditto, and coking.
„ —, „ -	Peake - -	Ditto - -	Ditto.
April 8, „ -	West Yorkshire Iron and Coal Company.	Ardsley, near Leeds	Ditto, and coking.

Clay-band ironstone.

In order to prepare the "clay-band" ironstone, which is the ore most largely raised in this country, for being smelted, it is necessary to calcine it; and this calcination is usually, although not always, done in the locality of the mine, even when the ore has not to be used there. The reason of this is that the bulk of material is lessened and its transportation is thus facilitated. Clay-band ironstone consists in great part of carbonate of iron, the other largest constituents being silica and alumina, but it also contains small quantities of lime and magnesia, with a little phosphoric acid and sulphur. What is termed the "black band" is black in colour from containing coaly matter mixed up in it. The object of the calcination is to drive off carbonic acid, to raise the protoxide of iron with which it was united to the state of peroxide, and, by altering the physical condition of the ore, to render it more easy of reduction in the furnace.

Methods of calcination: in clamps;

Two modes of calcination are practised, namely, in clamps and in kilns. In clamp calcining of ordinary grey clay ironstone it is customary first to spread a layer of coal in lumps upon the ground, and on this to raise the heap of ironstone, interspersing coal occasionally, and then to cover the surface of the heap with slack. In calcining "black band" it is not necessary to use any coal, there being sufficient carbonaceous or coaly matter in the stone itself, and often also adhering to the surface of the lumps, to furnish the necessary combustible material. The heaps thus formed are made about 6 or 8 feet high, sometimes much higher; they are made of variable extent, and sometimes are so large as to cover half an acre of land. Sometimes, as in brickmaking, the calcined stone is being removed from one end while the heap is being freshly made at the other end. The heap is then ignited and burns through in a smouldering way, emitting a good deal of smoke, a little flame breaking through the surface also in places. An ordinary sized clamp takes about three weeks to become thoroughly calcined, and at the end of this time its bulk is found to be reduced to about half what it was originally.

in kilns.

For calcining in kilns an ordinary open kiln, like a common egg-shaped lime-kiln, is sometimes used; but for the most part iron cup-shaped

kilns, made of iron plates lined with firebrick, are used. They are about 24 feet high, and are so arranged that while the ore and fuel can be fed in continuously above, the calcined ore is discharged at the bottom either upon a raised platform or directly into the waggons that are to carry it away. The kiln being once ignited, all that is necessary is from time to time to throw in a layer of coal on the top of a charge of stone. Mr. Wright, manager of the works at Ardsley, says that each of the calcining kilns which are used there is constructed to hold about 250 tons of stone, and that the quantity of coal used is about seven per cent. of the weight of the stone calcined.

Nuisance.

The calcining of ironstone in clamps is often a very great nuisance, and it is especially so when it is carried on, as it is in some places, such as some parts of North Staffordshire, in the immediate neighbourhood of a town and close to inhabited houses. The nuisance arises from the large quantities of sulphurous smoke emitted during the period of burning, which has all the objectionable characters as respects its influence upon health that have been mentioned when referring to the subject of "coking." The smoke and sulphurous fumes sweep for a long distance along the surface of the ground before they become so far dispersed as to be unobjectionable. Of course smoke of the same suffocating character issues from the open tops of calcining kilns, but it is very much less in amount, and is delivered into the atmosphere at a higher level. I have never found the smoke from such kilns so bad as to constitute anything like a serious nuisance at a distance of 100 yards. The reason of this is, first, that not more than one tenth of the quantity of coal is used that is used in clamp calcining, so that much less smoke is generated; and, secondly, that the smoke which is made is not emitted at the ground level, and consequently disperses more speedily.

Prevention of nuisance.

The use of kilns, then, instead of burning the stone in heaps on the ground, would appear to be the natural remedy for the nuisance of calcining ironstone; and whenever the nature of the stone permits of kiln calcining, this method of calcining alone ought to be pursued in localities where nuisance is likely to arise, or does arise, from calcining in clamps. But there is a limit to the use of the kiln. It is applicable to the ordinary grey ironstone with which coal has to be used for calcination, since, if the quantity of coal be not excessive, that is to say, if it be not used in greater quantity than is necessary to effect the calcination, the calcined stone falls out from the kiln in separate pieces; but it is not applicable to the black-band ironstone or the "red shag" of North Staffordshire, inasmuch as these stones become partially fused during calcination, and run together into large blocks and masses which require a pick-axe to break them down. The calcined stone would not run out from the kiln.

Calcination of Tap-Cinder.

Calcination of Tap-Cinder.

"Tap-cinder" is the slag drawn out from puddling furnaces in which pig iron has been made into malleable iron. It consists mainly of protoxide of iron and siliceous matter, the latter partly derived from the bricks with which the reverberatory furnace is lined. In fact it is the bath of "fettle," rich in peroxide of iron, which in the process of puddling has given up its excess of oxygen to oxidise the carbon, silicon, sulphur, and phosphorus which the pig iron contains, and which have in the process of puddling to be as far as practicable removed. The tap cinder, in order to fit it again for use in fettling, requires that the iron it contains should be again peroxidised. Tap-cinder also is sometimes used as a material for smelting, the pig iron made from it being known as "cinder-iron." In either case it has to be peroxidised by calcination

Process of making bull-dog.

When it is to be prepared for use in "fettling," that is, for lining puddling furnaces with the object above described, the calcination is performed in what is termed a "bull-dog" kiln, the resulting material going under the technical designation of "bull dog." A bull-dog kiln is constructed very much like a Scotch brick kiln, 9 or 10 feet high, with side walls having opposite fire openings at intervals; and the tap-cinder to be calcined is first built up at the bottom so as to form channels or passages from the fire openings on the one side to those on the other. The cinder broken up is then filled in, with alternating layers of coal, up to the top of the kiln. The ends are bricked up and the kiln lighted: it burns out in about a week. The fire must not be too fierce, or the tap-cinder merely melts down, and may then form a hard mass which can scarcely be extracted except by blasting. When the kiln has gone out, the calcined material or "bull dog" is found in a coherent mass which has to be broken down with a pick.

Calcination in clamps.

For making cinder-iron it is customary to calcine the cinder in a large clamp or heap, perhaps 25 feet high, containing many thousand tons of it. The heap is made much in the same way, with coal at the bottom and interspersed, as an ironstone clamp. I understand that six or seven cwts. of slack are used to each ton of cinder. A large heap, Mr. Grocutt tells me, burns out in about a fortnight.

Nuisance.

The nuisance from calcining tap-cinder is similar to that from calcining ironstone, consisting in the smoke and sulphurous acid emitted in the operation. It is greatest when proceeding from the clamps, perhaps on account of the very much larger mass under combustion at one time. I have nowhere seen any effort made to lessen the nuisance in any way; but I cannot help thinking that where "bull-dog" kilns are a nuisance, as they may be in a town, something might be done by means of an iron roof or shed, from the top of which the smoke and vapours evolved might be conducted to the chimney shaft of the works, to lessen the nuisance. As respects clamp calcining, Mr. Grocutt told me, in conversation on the subject, that he had made cinder-iron without any previous calcination, and had found no difference in the iron produced; so that it is open to question whether the process and its attendant nuisance are not both superfluous.

Ignition of Waste Heaps of Iron works.

Ignition of Waste Heaps of Iron works.

Two kinds of waste products at iron works have to be disposed of, namely, the slag from the smelting furnaces, which consolidates on cooling into large square or cylindrically-shaped blocks, and the clinkers and ashes from puddling and boiler furnaces which sometimes contain, mixed up with them, unconsumed morsels of coal. Both of these waste products are removed separately in waggons or barrows, as the case may be, from works, and shot down upon a heap or "tip" outside, while in a hot and ignited condition. They may be thrown upon separate tips or both upon the same tip. Enormous hills of such refuse are common objects in the iron-smelting districts. Slag heaps, if containing no ashes, or coal or "bass," cannot fire; they are mere heaps of blocks of glass; but when a heap of ashes fires, the nuisance may scarcely be tolerable if the heap be in the vicinity of inhabited houses. Its character is much the same as that of the nuisance from an ignited spoil bank (p. 106); and where no effort is made to lessen the nuisance, but additional material is daily thrown on the heap, the nuisance is a constant one. Such fiery mountains as I am describing are commonly to be met with about extensive iron works. But common as the nuisance is, it is quite unnecessary and quite avoidable by the exercise of a little care. The

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slag and ashes, &c. ought not to be mixed in the same tip, otherwise the latter are certain to become ignited and burn. As regards the ashes, the practice I saw pursued at Stanier & Co.'s works at Silverdale is commendable and prevented nuisance, and might be pursued everywhere. The ashes, &c. were brought to a tip of their own, and, as soon as they were thrown from the barrow, were raked out into a thin layer on the surface where they rapidly became extinguished. Part of them were washed by hand to separate the breeze from the clinkers, the breeze being bought at a good price, 4*s.* 6*d.* per ton, by the breeze merchants.

HARDENING OF STEEL SPRINGS AND SAWS.

Establishments visited.

ESTABLISHMENTS VISITED.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 3, 1876 -	Hasker and Skelton	Nottingham -	Manufacture of lace-maker's "springs and points."
May 17, 1878	S. S. Brittain -	Sheffield - -	Manufacture of saws.
" " " -	Cocker - -	Ditto - -	Wire drawing.
" " " -	Cocker & Co. -	Ditto - -	Manufacture of carriage and umbrella springs.
" " "	Wheatman and Smith.	Ditto - -	Manufacture of saws.

Process.

In order to permit of the proper shape being given to springs, the steel must be soft and flexible, in which condition it will retain the shape imparted; but subsequently it has to be hardened. It is this hardening process which sometimes gives rise to nuisance. Lace-maker's "springs" and "points" are quite small articles, made of steel wire, the former being about 1½ inches to 2 inches long and the latter about 3 inches long, and of about the substance of a strong worsted needle. The process, as I saw it carried on in Nottingham, is as follows. The articles are first put into an iron tray, and in it introduced into a shallow iron muffle, which is heated by a small fire and covered over with a piece of iron. When they are red hot the tray is removed, and its contents are thrown into a pot of cold refined seal oil. When they are cold they are very brittle, and the object of the further process is to reduce this brittleness. For this purpose they are transferred to a saucepan of seal oil, in which they are heated over an open fire, the pot being removed from the fire from time to time in order that the degree of tempering of the steel may be tested.

Spiral steel springs for chairs, &c. and saws are also hardened by immersion in oil while at a red heat. The mixture used for spiral springs at Cocker's works is, I was informed, made of 9 gallons of whale oil, 1 stone of resin, and a ½ stone of tallow. At Cocker and Co.'s works I was informed that nothing but whale oil is used. Saw makers use either whale oil or a mixture similar to that used for spiral springs, but in either case with the addition of a little Venice turpentine. When large articles, like long or circular saws, have to be hardened, the trough containing the oil must be large also in order to receive them; and whether it be large or small it stands open and exposed in the workshop, which is either ventilated by open side windows or through openings in a low roof.

Nuisance.

The nuisance complained of is the evolution and diffusion of vapours of acrolein in the neighbourhood; these vapours arising from the

heating of the oil to the point at which it undergoes destructive change. (See Second Report, page 117, article "Oil-boiling.")

Prevention of nuisance.

Where any of the processes just described cause offence to the neighbourhood, the nuisance may be readily obviated by enclosing the pot or vessel from which the acrolein vapour proceeds within an iron closet or cover, having provision for convenient access, and by drawing off the vapours evolved, and disposing of them by one of the means adopted by oil boilers or varnish makers to prevent nuisance from their works. (See "Oil boiling.")

SPELTER WORKS.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 11, 1876	Ryland - -	Warrington.	—
June 27, 1878	Crown Spelter Works.	Swansea.	—
Jan. 6, 1879	Upper Bank Spelter Works.	Ditto.	—
" 13, " -	Vivian - -	Morriston, Swansea.	—
Mar. 21, " -	Jones - -	Wolverhampton.	—
May 16, " -	Bagillt Smelting Company.	Bagillt.	—
" 20, " -	Kennyon - -	Warrington.	—

Materials used.

The ordinary ores of zinc from which commercial zinc or "spelter" is made in this country are "blende," which is a sulphide, and "calamine," which is a carbonate of zinc. Of late years a practice has also arisen of recovering the zinc which exists in the scum taken off the pots of metal used in the galvanising of iron, a substance known as galvaniser's scum (p. 244). At two works which I visited where this material is used, the zinc obtained from the scum in the form of oxide was smelted on the premises. At a third work that I visited, the oxide was not smelted, but was sent off the premises as oxide.

Process.

When the ores above mentioned are used, they are first calcined; the object being to burn off the sulphur and to oxidise the zinc in the case of blende, and to drive off the carbonic acid and dry the ore and render it less compact in the case of calamine. This calcination is performed in a reverberatory furnace very similar to that used for calcining copper ores, or else constructed in two floors or beds one above the other, the ore being first exposed to the heat on the upper bed, and then to the greater heat on the lower bed. The calcined ore is then mixed with coal dust, preferably from anthracite or non-caking coal, and the mixture is charged into the retorts. There are two methods of extraction chiefly in use, known as the Belgian and the Silesian methods. In the Belgian method cylindrical fire-clay retorts, closed at one end, about 3 feet long and 6 to 8 inches wide, are used, and they are arranged in tiers within a chamber in which they thus lie across from front to back. The closed ends are tilted up a little at the rear, where they are supported upon notches in the back part of the chamber, the front open ends of the retorts being supported upon cast-iron ledges. To the mouth of each retort is luted a fire-clay nozzle about 12 inches long, and bellied out below, which, being outside the chamber, acts as a condenser. On the end of each nozzle or condenser a conical iron tube is fitted.

The fireplace is situated beneath the lowest tier of retorts, and the heated air and products of combustion rise up among the retorts, and after serving to reduce the zinc are not unusually made to pass into the calciner, which for this purpose is placed on a higher level. During the first part of the reduction process a blue flame of burning carbonic oxide is observed at the end of the nozzle; but after a time the flame assumes a greenish white colour, and is more luminous, due to the burning of fume of metallic zinc, and at the same time clouds of white vapour, which is oxide of zinc, escape into the chamber. It is to save this that the iron conical tube is put on the end of the condenser. The greater part of the zinc collects in the fire-clay condenser, and is raked out from time to time. The retorts used in the Silesian method of extraction are ∩-shaped, about 18 inches in height, and about 8 inches wide. There are two apertures in the front part of the retort, an upper one to which the fire-clay condenser is attached, and a lower one by which the charge is introduced and the residue of the process is removed, and which is closed up during the smelting process. At the Upper Bank Spelter Works at Swansea, and at Morriston, Siemens' gas apparatus was being used in this process as a source of heat.

Nuisance.

The complaints of nuisances I have heard of in respect of the treatment of ores of zinc and their reduction, have had reference to the evolution of sulphurous acid fumes, and of white dust proceeding from the works; but this white dust has no odour. The sulphurous acid, of course, proceeds from the burning off of sulphur during calcination, which should be, and I believe is, always carried on until the ore is "sweet," that is to say, until no sulphurous acid is evolved when the charge is drawn. The white dust is the oxide of zinc which rises from the roof or openings in the works, and is carried away by the wind. Where, as at Swansea, other works emitting sulphurous acid abound, the nuisance proceeding from this particular source is undistinguishable from that proceeding from other sources.

Prevention of nuisance.

In one instance where sulphurous fumes were distinctly a nuisance a remedy was found in carrying them by a flue, said to be 300 yards long, away from the houses in the neighbourhood and up a hill, where they are now discharged from a chimney shaft 180 feet in height. In dealing otherwise with these fumes, as for instance in condensing them, there would be the same difficulty that is experienced in the case of copper fume.

Galvaniser's scum.

Galvaniser's Scum.—Mr. E. W. T. Jones, of Wolverhampton, the public analyst for the county of Stafford, has given me the following as the result of an analysis which he obligingly made for me of an average sample of this material, after removing the few spots of zinc that were mixed with it:—

Chloride of zinc - - - -	41·62
Oxide ,, - - - -	32·53
Chloride of ammonium - - -	13·00
Silica - - - - -	1·15
Oxide of iron - - - -	2·55
Tin - - - - -	Traces.
Arsenic - - - - -	Traces.
Lead - - - - -	Traces.
Water (by difference) - - -	9·15
	100·00

This material is not treated in the same way by all the manufacturers who deal with it. One method, and that the best, so far as I can judge by the results obtained, I am prohibited by the manufacturer from describing; but it is nearly free from nuisance, and what little nuisance there is, is in progress of being remedied. By another method, the soluble matters are simply taken out by solution in cold water and crystallised, with the result of obtaining a mixture of salts, namely, of chloride of ammonium and chloride of zinc, which is again sold as flux to the galvanisers, while the insoluble matter is calcined and reduced in the ordinary way. This proceeding gives rise to no nuisance. But at one establishment where scum was dealt with, the nuisance was so great that the Sanitary Authority had to interfere for its suppression, and the works are now closed. At these works the soluble part of the scum was dissolved out with hot water and re-sold as flux, while the residue was calcined. But in addition, there was another process in use by which the zinc was precipitated in large open tanks with an ammoniacal liquor prepared by the distillation of gas liquor, which distillation was carried on upon the premises. The fumes proceeding from these processes were exceedingly offensive.

THE GALVANISING OF IRON.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 15, 1876	Ryland - -	Warrington -	(Wire works.)
May 1, „ -	Pinson and Evans	Wolverhampton.	—
Mar. 27, 1878	R. Johnson -	Bradford, Manchester.	—
June 19, „ -	Porteus and Crawford.	Glasgow.	—
Jan. 23, 1879	Morewood & Co. -	Birmingham.	—
Mar. 21, „ -	Bishton - -	Wolverhampton.	—
„ „ „ -	Davies Bros. -	Ditto.	—
„ 22, „ -	Corrugated Iron Company.	Ditto.	—
„ „ „ -	Gospel Oak Galvanizing Works.	Ditto.	—
Nov. 26, „ -	Braby - -	Glasgow.	—

The process of "galvanising" consists in covering iron with a coating of zinc. It is applied to sheet iron (corrugated or not), iron wire and netting, iron pails, &c. At large works the sheets are rolled, and the wire is drawn as well as galvanised.

Process.

Galvanising is performed by dipping the iron into a bath of zinc; but prior to the dipping, the iron has to undergo some preparation so as to fit the surface to receive the layer of zinc. This preparation consists in cleaning the surface by dipping the articles into an acid bath. This is called "pickling," and the acid bath is technically termed "pickle." The pickle consists usually of hydrochloric acid properly diluted, and is used cold, except that in cold weather it is sometimes warmed a little by the injection of steam; but at the Gospel Oak Works diluted sulphuric acid, made to boil by throwing in steam, is the pickle employed for sheets of iron, hydrochloric acid only being used for wire, pails, &c. The pickle for sheets of iron is usually contained in a deep stone trough, into which the sheets and other articles are dipped by hand, and where they are left for a sufficient time. On being removed they are at some works washed with water, but at other works this washing is dispensed with. Again, at some works the pickled plates are next dried over a coke fire.

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but at other works they are simply at once transferred without drying to the metal bath. In the case of wire there is sometimes a modification of the acid bath, which is made broad and shallow, so that the wire can be slowly drawn through it on its way from the reel to the metal bath, while at other works the wire is dipped in the form of a coil.

The metal used is commercial zinc known under the designation of "spelter," to which, when it is required to impart a crystalline appearance to the galvanised surface, a small proportion of tin is added. The metal bath is of iron, and is heated by a fire beneath. Its form and arrangement vary in different works. In some it is merely a long narrow bath of sufficient depth to receive the sheet, and the sheet is let down edgewise into it, and raised in a similar way. In other cases the bath has an iron bar along the middle dipping into the metal, so as to divide the top of the bath into two compartments represented in Fig. 35, p. 247. The sheet is dipped down into the compartment on one side, and then being made to bend upwards, is raised on the other side of the bar, thus making the circuit of the bottom of the bath. At the Corrugated Iron Co.'s works at Wolverhampton there is a third mode of dipping in use. The bath is in this case shorter, and is furnished with rollers working in the metal; the sheet is dipped in its shortest diameter, and passes up again between the rollers, from which it is delivered, covered with a thin layer of zinc. The arrangement is thus similar to that in use at tin-plate works. Some chloride of ammonium is sprinkled on the surface of the bath from time to time for the purpose of cleaning the surface of the melted spelter by absorption of the oxide formed (this melted "flux" protecting the surface from undue oxidation). When it has been mainly transformed into an oxychloride of zinc, it becomes objectionably viscous, as well as practically inactive for absorption of the oxide, and is then removed by skimming. The scum thus removed from the bath is termed "galvaniser's scum." and is now the subject of a special industry for the recovery of th spelter and the chloride of ammonium which it contains (p. 242). When a bar is as above-described laid along the top of the metal bath, the flux is only used on the side on which the plate is dipped, or, in the case of galvanising wire, on the side at which the wire enters the bath. As the wire passes out of the bath through which it is drawn on to a reel, it is drawn through sand laid upon the melted metal on the exit side of the bar. At some wire works no sal ammoniac is used, but the wire is passed directly from the pickle into the bath.

Nuisance.

Galvanising works are very commonly a source of nuisance to the immediately surrounding neighbourhood, on account of the fumes which issue from the openings in the sides and at the roof of the workshops, from which white fumes are seen arising. The odour complained of is of a mixed character, partly acid and partly alliaceous or arsenical. The acid odour is not a purely acid odour, but has another odour of a peculiar kind mingled with it, an odour which I only know as attaching to hydrogen gas developed by the action of acid upon common iron. I have heard people complain of the fumes from galvanising works as "suffocating," and as producing headache and sickness, and generally making them feel ill. I have seen several persons who have been frequently exposed to these arsenical fumes in the immediate neighbourhood of works whence they have proceeded abundantly, and all have given me the same account of the effect they had upon them. They say that the headache produced is very intense, and lasts for many hours, incapacitating them from work, and that in addition they felt "as if they were blown up." There really appears to occur some amount of actual abdominal distension. (*See also* p. 287). The sources from which the offensive fumes proceed are the following, viz. :—

Injury to health.

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Sources of nuisance.

1. If the "pickle" be used hot, acid steam is evolved from the bath, and whether it be used hot or cold, hydrogen gas is evolved having the peculiar odour above referred to.* When the pickling tanks are situated near an open window, as is often the case, the acid fumes escape from the building at a low level, and are then much more likely to produce nuisance than when they issue from the roof.

2. The white fumes and the arsenical odour proceed from the bath; the arsenical odour is always more or less noticeable in the dipping shop, even if it be not noticeable outside the building. The white fume is given off in greatest volume when fresh chloride of ammonium is thrown upon the bath. Commercial zinc is never quite free from arsenic, but the quantity varies. Mr. E. W. T. Jones, F.C.S., the public analyst for the county of Stafford, in whose company and with whose introduction I visited the galvanising works in Wolverhampton, has been good enough to determine for me the quantity of arsenic in three specimens of spelter which I found in use at three separate works where arsenical fume was more or less noticeable. His results were as follows:—

	Arsenic.
10 gms. Silesian spelter used at Bishton's; the smallest trace	Not weighable.
10 „ English „ „ Davies's, a trace -	Not weighable.
20 „ „ „ „ Corrugated Iron Company	0·012 per cent. = 3 oz. 18 dwt. 9 grs. per ton.

Of the three works the arsenical odour was most obvious at the last, both within the workshop and in the yard outside; at the other two works it was only moderately noticeable within the workshop, and not at all outside. But it is to be remarked that a galvanising firm does not always use the same kind of spelter.

At the Corrugated Iron Company, as I shall have occasion to mention immediately, some of the white fume from the metal baths is collected, and of the collected dust Mr. Jones kindly made an analysis for me, with the following result:—

	Per cent.
Chloride of arsenic -	2·85 = 1·18 of arsenic.
Chloride of zinc - -	28·87
Chloride of ammonium -	53·60
Silicious insoluble matter -	9·02
Iron, alumina, &c. and a trace of tin (by difference) - -	5·66
	100·00

This sample of dust was collected from the flue close to the fan to be presently mentioned.

* With reference to the nature of the substance which renders the hydrogen gas odorous, I have the following note from Mr. C. Tookey:—"When iron containing "carbon in combination, *e.g.*, in 'spiegeleisen,' is acted upon by hydrochloric or "sulphuric acid, the carbon unites with some of the nascent hydrogen and forms "various hydrocarbons, which have a petroleum-like odour. We [referring to "some investigations made by him in Dr. Percy's laboratory] obtained nearly "two ounces of these compounds by the action of sulphuric acid on spiegeleisen, and "I afterwards separated them by fractional distillation into six portions, the boiling "points ranging from 200° to 270°. I found that the last distillate, which was an "amber-coloured oily fluid, had a composition isomeric with olefiant gas. Then, "when iron containing sulphur and phosphorus is acted upon in like manner, "we get sulphuretted hydrogen and phosphuretted hydrogen, the escaping gas "having a most offensive stink. The hydrogen is said to be fetid."

Effect of waste pickle on sewers.

3. At most galvanising works the waste pickle is run off into the drains and so into the public sewers, where, being still acid, it may give rise to the evolution of sulphuretted hydrogen from the street gully-gratings and the untrapped drains of private premises, in consequence of its decomposing the sulphides in the sewage. Moreover, the acid acts injuriously upon the sewers through which it passes. At the request of the Corporation of Wolverhampton Mr. Jones has on two occasions, viz., in 1877 and 1878, chemically investigated this subject, and has been good enough to furnish me with his reports and the results of the analyses he made. The following is his analysis of spent pickle taken at the works of the Corrugated Iron Company on 1st March 1878 :—

	Grains per Imperial Gallon.
Ferrous oxide (protoxide of iron) - -	6165·72
Ferric „ (peroxide „) - -	70·50
Combined chlorine - - -	6485·85
„ sulphuric acid - - -	184·80
Free hydrochloric acid - - -	3423·70

On another occasion he found the hydrochloric acid present as follows, viz. :—

Combined - 6847·4 grains per imperial gallon.
Free - - 3781·4 „ „ „

Showing in both cases about one third of all the acid free and not neutralised.

The following table, copied from Mr. Jones's Report to the Corporation, dated 1st October 1877, represents the results of analyses of eight samples of liquid flowing from different galvanising works into the public sewers in August and September of that year :—

—	In Grains per Imperial Gallon.							
	A.	B.	C.	D.	E.	F.	G.	H.
Total solid matter dried at 100° C.	106·40	5398·40	308·00	330·40	10998·40	420·00	1192·80	484·4
Iron - - -	21·76	1040·66	71·07	33·36	2436·67	43·51	314·73	111·68
equal to Green vitriol - -	108·02	5166·13	352·81	165·60	12096·33	215·97	1562·42	554·41
or about	¼ oz.	11¾ oz.	¾ oz.	⅓ oz.	27¾ oz.	½ oz.	3½ oz.	1¼ oz.
Hydrochloric acid -	67·45	5007·80	184·98	166·58	9185·22	214·62	945·35	419·02
Sulphuric acid (SO_3)	2·40	50·47	14·42	4·80	40·86	2·40	9·61	14·42
Zinc - - -	little	large amount.	little	little	large amount.	little	little	little
Lime required to precipitate all the iron.	51·7	3841·5	141·90	127·8	7046·2	164·6	725·2	321·4
or about	⅛ oz.	8¾ oz.	⅓ oz.	¼ oz.	16¼ oz.	⅓ oz.	1½ oz.	¾ oz.

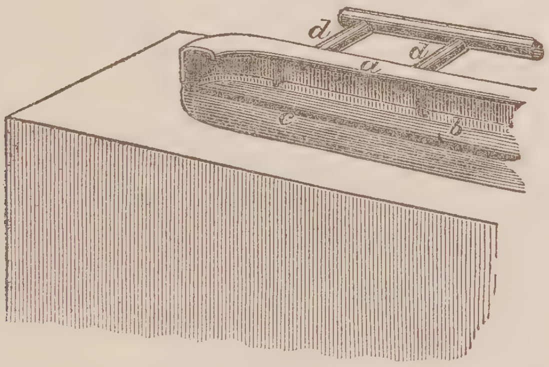
The following may be taken as a summary of Mr. Jones' observations upon the subject :—1. The spent pickle discharged is ordinarily an acid solution of chloride of iron; where sulphuric acid is used sulphate of iron will be the salt in solution. 2. Spent pickle, where oil of vitriol is used, would not damage the fabric of the sewers to anything like the extent that spent hydrochloric acid would, because the latter forms a very soluble salt with the lime of the mortar. Unfortunately, it is the hydrochloric acid which is mostly used. Sometimes, in consequence of the carelessness of the men, the pickle is run off before two thirds of the acid have been neutralised.

Prevention of nuisance.

I am not acquainted with any works in which any attempt is made to prevent the escape of acid offensive vapours or gases from the pickling process, except in the instance of Johnson's works at Bradford, near

Manchester, where wire is pickled by running it through a shallow bath of acid in its course to the metal bath. At these works a wooden hood is brought down closely over the bath, resting on its edges, and having provision made at the lower edge in front and behind for a row of wires to pass under its edge into the bath, and similarly out again on the opposite side. There are several such baths and hoods, and all of the hoods communicate above with a main 12-inch stoneware pipe, which conveys the vapours given off to the bottom of a 30-feet coke scrubber or condensing tower, down which water is made to trickle. This arrangement was adopted in order to do away with complaints of nuisance, and it has been effectual in that respect. Of course a close-fitting hood of this kind would be inapplicable to baths for pickling sheets of iron or other articles that have to be dipped by hand, but I can see no reason why a modification of it should not be generally adopted, the bath being enclosed within a hood sufficiently open on one side to allow of the operations of the dipper. With respect to the fumes from the metal bath, the only thing at all frequently met with and used to obviate annoyance, is an iron hood descending from the roof of the workshop over the bath, but only so far down as to allow of the dippers passing beneath its edge; above it usually communicates with a short chimney in the roof. This serves to conduct the fumes out of the building at the roof, and so to prevent their general diffusion in the workshops, and is rather a provision for the comfort of the workpeople than for that of the outside public. But some works have not even this provision. The only satisfactory method of collecting the fume, and of obviating in this way public annoyance, that I have seen, is at the works of the Corrugated Iron Company at Wolverhampton. The arrangement is represented in Fig. 35,

Fig. 35.



and has been patented by Mr. Joseph Jones (1868, No. 3,871). Upon the upper edge of the bath and surrounding one half of it (that side at which the sheet rises out of the bath) there is constructed a flat flue *a*, which is open where it overhangs the metal in the bath *b*, to the extent of a few inches; *c* is the bar or septum of iron described before as traversing the length of the top of the bath in the middle. From the open flue several pipes *d d* proceed and enter a main pipe. The main pipes from several baths enter a flue provided with an exhaust fan worked by steam power, by which a strong draught of air is occasioned, which sweeps across the surface of the bath, carrying with it all the fume which is created into the pipes proceeding from the overhanging open flue or gutter. The fume condenses in the flues to a great extent, and might with appropriate arrangements be condensed even more than it is. So much of it as is not condensed is conducted to a chimney shaft and discharged into the atmosphere at a height of 125 feet. Mr. Jones has adapted this arrangement to all his baths which are of the construction depicted; he expects shortly to be able to adapt it to the roller baths

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also. It is obvious from Mr. E. W. T. Jones' analysis of this fume that its collection, while beneficial to the public, might also be found advantageous to the manufacturer.

Mr. E. W. T. Jones finds that the best way to deal with the spent pickle is to neutralise it with limestone before permitting it to be discharged into the sewers. This serves to dispose of the free acid; and the discharge of the neutral salt to mix with the sewage is rather an advantage than otherwise as serving to deodorise it. He finds that the cost of neutralising the free acid in this way is one halfpenny for every carboy of muriatic acid purchased by the manufacturer. I found this method in use at the works of the Corrugated Iron Company. The saturator here is a circular brick well, with a dip-stone in the middle reaching within 3 inches of the bottom. Both of the divisions thus constituted are charged with blocks of limestone put in as loosely as possible. The spent pickle from the works runs in at the upper part of the first division, has to pass down to the bottom and up to the outlet at the upper part of the second division. I found the neutralisation complete, and even the ferruginous taste in the effluent water by no means strong, some of the iron having been precipitated. Where sulphuric acid is used, limestone is ineffectual, and precipitation with cream of lime has to be substituted.

THE TINNING OF IRON—THE TIN-PLATE MANUFACTURE.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 1, 1876	Baldwin - -	Wolverhampton.	—
July 24, ,, -	Thomas - -	Lydney - -	Puddling and rolling of iron.
June 28, 1878	Landore Tin-Plate Works.	Swansea.	—
Jan. 9, 1879	Ynys Pontardawe Tin-Plate Works.	Clydach, Swansea -	Ditto, and coking.
,, ,, ,, -	Cwm Felin Tin-Plate Works.	Swansea - -	Ditto, ditto.
,, ,, ,, -	Cwm Brwla Tin-Plate Works.	Ditto - -	Ditto, and manufacture of green vitriol.
,, 10, ,, -	Morewood & Co. -	Llanelly - -	Ditto.

Process.

The process of tin-plate making consists in covering plates of rolled sheet iron with a layer of tin. It is in many respects similar to the process of galvanising. At large establishments of this kind it is customary to puddle and roll the iron which is to be used; but small makers buy their plates and simply tin them. The largest works of this kind that I have seen are about Swansea.

The plates have to be carefully prepared to receive the tin. 1. The rolled plates, cut to the desired size, are put in bundles of ten or twelve, with some sawdust sprinkled between them to keep them apart: the whole bundle, thus made up, is taken by a pair of tongs and dipped into the first or "black" pickle, which is contained in a lead-lined trough usually set against a wall. This pickle is oil of vitriol, diluted with water, in the proportion of about half a pint to a gallon. Steam is thrown in to raise the temperature, and heat the acid up to boiling point or thereabouts. While in the pickle the plates are moved about by the

workman, who judges by their appearance when they are sufficiently pickled. It is clear this process will occupy less time when the pickle is fresh than when part of the acid has been neutralised. The bundle is then raised with the tongs and laid in a trough of cold water to await the next process. 2. This consists in "annealing." The plates are packed in iron boxes and closely covered down, and are in this state run into an oven, where they are maintained for a proper time at a red heat; the boxes are then run out of the oven and allowed to cool. The plates are then rolled, annealed again, and rolled a second time. 3. The plates are then pickled a second time; this pickling is called "white" pickling. The acid is used weaker than for black pickling, but otherwise the process is similar. From the "white" pickle they are placed in a trough of cold water, where they lie until removed wet to the tinning shop. 4. The tinning shop is arranged thus: on one or both sides of the room there are placed the tinning pots, in what are designated "sets," each set containing the series of pots required for tinning. There is a hood coming down over each set so as to catch the vapours which arise and to conduct them into a low chimney, which chimney also receives the smoke from the fire beneath the tinning pots.

Figs. 36 and 37 (p. 250), are rough diagrams showing the arrangement of a set under its hood. It consists, as will be observed, Fig. 36, of five pots, through which each plate has to pass in order. No. 1 is a grease pan, containing palm oil, which is kept just sufficiently warm to be liquid. Into this pan a number of plates, still wet, are placed. Each plate is then taken out separately with tongs, and is immediately dipped into No. 2, which contains molten tin, and is termed the "tin-pot." The tin in this pot is covered with a layer of palm oil. This and the remaining pots are heated by fires beneath, but the tin is not heated much above its melting point. The palm oil on the surface of the tin appears in a state of ebullition, and foams over the edge of the pot, flowing from it into No. 1, which is thus kept sufficiently warm without requiring a fire beneath. Here the plates remain for some time, the workman moving them up and down occasionally. When he considers them sufficiently tinned, he removes them separately with tongs to No. 3, which is termed the "wash-pot" or "soaking-pot." It is a similar pot to No. 2, and its only use is for storing the plates preparatory to the next operation. It will be observed in the diagram that there is a greater width or interval in the set between Nos. 3 and 4 pots than between any of the others; this flat part of the surface of the set is used for the next operation. A workman takes a bundle of plates out of No. 3 and lays them flat before him, and then he brushes them on both sides, one by one, with a soft long-haired hand-broom, which he moistens from time to time in some clean melted palm oil. The object of this is to brush off the superabundant tin and the foul oil, which mixture of tin and oil he pushes away to the back part of the set against the wall for removal at the close of the day's work. As each plate is brushed clean, the workman drops it into No. 4 pot, called the "dipping-pot," which is again a pot of tin covered with palm oil, but, in this case, fresh and clean palm oil. Here another layer of clean tin is put on, and then another workman lifts out each plate separately and transfers it to No. 5, which is termed the "grease-pot." This pot is of a different shape and deeper than the others, since the plates have to pass between rollers and beneath the lower of them. It contains clean palm oil, in which five rollers work, three in a row above and two in a row beneath them. Each plate, as it is removed from No. 4 pot, is slipped in between the one pair of rollers in the upper row and then made to rise out of the grease bath between the two pairs of rollers. The object of this is to smoothen the

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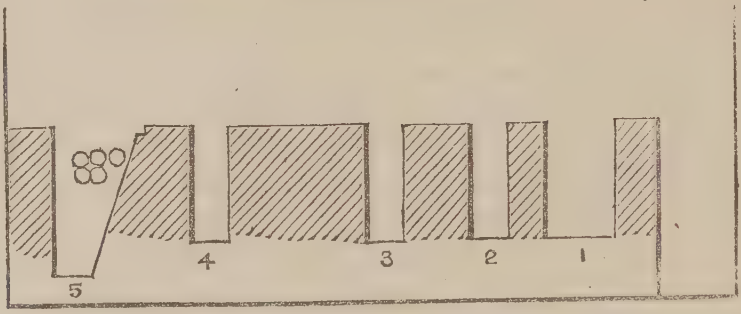
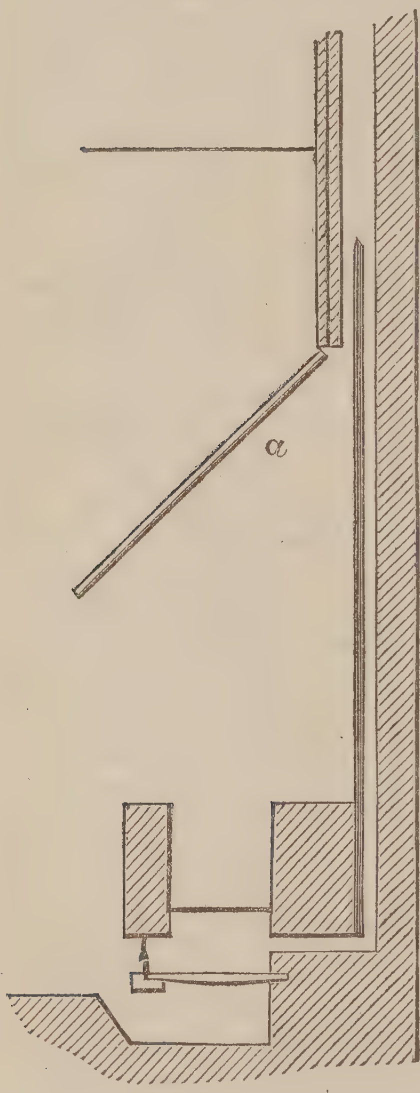
surface of the plate and to regulate the thickness of the layer of clean tin. Each plate is then scrubbed with bran before being sent into the

FIG. 36.



sorting-room. The foul and foamy grease is occasionally skimmed from the top of the pots and thrown back with the sweepings of the plates; this refuse is known as "scruff," and is dealt with subsequently for the recovery of the tin. The process described is that almost universally followed, but in one establishment I observed the substitution of a diluted muriatic acid bath for the grease bath No. 1. In making what are termed "terne" plates, a mixture of two parts of lead and one part of tin is used, instead of tin alone: otherwise the process is the same. The "scruff" is utilised thus: the grease is melted out of it and is used for lubricating machinery, and the metal is melted down in a small reverberatory furnace and run into moulds. This metal, not being so clean as new tin, is only used in No. 2 pot to mix with fresh clean tin. Abundant fumes are evolved in the process of tinning and are collected by the hood *a*, Fig. 37, and conducted by it to a low chimney which rises usually only a few feet above the eaves of the building. What rises from No. 1 pan is chiefly watery vapour, but there is no watery vapour to rise from the other pots. The fumes from these consist of acrolein vapours resulting from the destructive distillation of the oil, and of particles of grease thrown up with them from the apparent ebullition which accompanies this decomposition. The inner surfaces of a hood and chimney which have been in use for some time are found to have a coating of this greasy matter collected upon them.

FIG. 37.



Nuisance.

The offensive effluvia from tin-plate works are disagreeably perceptible, if the works be extensive, for some distance around them. I have myself perceived them disagreeably at a distance of 300 yards from the works, when the wind has been in the right direction. They consist of acid fumes, and the peculiar odours of palm oil and acrolein intermingled; the latter appear to travel much further than the acid fumes. Much smoke also is given off when the iron is puddled and rolled on the premises. The acid vapour, mixed with the peculiar odour accompanying the evolution of hydrogen gas (referred to at

p. 245), proceeds from the hot pickling process; the source of the palm oil and acrolein odour has been sufficiently indicated above. Both kinds of fume are evolved at a low level.

Prevention of nuisance:

from pickling;

The plan adopted at the Landore Tin-Plate Works is one which is calculated to obviate nuisance from the acid fumes, and does obviate nuisance there to a considerable extent. Instead of dipping the plates by hand as is customary, the "black" pickling is effected in close lead-lined boxes so supported as to permit of their being rocked backwards and forwards. So long as the cover is kept on, and during the rocking, no acid fume escapes; this only occurs when the lid is removed for the removal of one set of plates and the introduction of another set, which proceeding occupies about five minutes. The "white" pickling is performed in another manner. The pickle is put into a wide, comparatively shallow tank, at each opposite side of which is a roller, and several endless copper chains pass round them, and through the pickle, at intervals of about 8 inches. The plates are laid on the chains on one side and carried upon them through the pickle to the other side, where, as they come out, they are washed with water which falls upon them from a pipe in that situation. In order to catch the fume which arises, a wooden case is constructed over the tank and inclosing it, and from the top of the case a wooden pipe or channel conducts the fume away to a culvert underground which drains the works. An exhaust jet of steam is thrown into this channel to draw off the fume which then condenses in the drain. All that appears wanting to render such an arrangement as this complete is a hood over the rocking boxes communicating with a chimney shaft.

from tinning.

The fact that some of the oily fumes which escape from the tinning pots do become condensed or deposited about the interior of the hood, seems to indicate the appropriate remedy for nuisance from this source, namely, connecting the upper parts of all the hoods with a sufficiently long flue which should conduct the fumes into one tall chimney. I confess I have been wholly unable to comprehend why, unless it be merely to accord with the traditions of the business, the practice of using a number of small chimneys is so universally maintained. It is the same in newly-constructed works as in old ones. Talking to Mr. Rogers, the manager of Morewood & Co.'s works at Llanelly, which works are comparatively newly erected, and a model of good construction and cleanliness, he told me that they had, while building the works, contemplated making all the sets on one side communicate with a single chimney; but that the idea was abandoned partly because it was feared that the prejudices of the workmen might have been crossed, and partly because it was thought that possibly the draught upon the several hoppers in the row might not be uniform. But the latter difficulty might have been met by the judicious use of dampers. By collection of the fume in one flue facilities would be afforded for washing it, if necessary to condense the acrolein, or for carrying all the fume through a fire.

Disposal of waste pickle.

Tin plate works, like galvanising works, have to dispose in some way of their spent pickle. In some works this is done by boiling it down and crystallising the sulphate of iron it contains. The spent pickle being acid with sulphuric acid, the boiling down has to be performed in a lead-lined vessel, and it is accompanied by the evolution of acid fumes. Any nuisance from this source may be obviated by covering the vessel and condensing the steam in any of the ways which have been mentioned under the head of sulphuric acid making (p. 181). Where the spent pickle is not thus utilised, it ought to be neutralised with cream of lime before being discharged into a sewer. (See "Galvanising of iron," p. 248.)

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Establishments visited.

TIN BURNING.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 4, 1878	Ward and other persons.	Bethnal Green.	—
„ 5, „ -	Lewis - -	Belle Isle - -	Metal washing.

Process.

"Tin burning" is a miserable trade, almost solely carried on by persons of the costermonger class in the open yards attached to their dwellings. Dust contractors who collect the matters which are thrown into London dustbins and sort and sift them in their yards, pick out and set aside for sale to these persons tinned iron articles which have any solder on them, such as Australian meat tins, lobster tins, potted meat tins, &c. The purchasers, who, so far as I can learn, mostly live in Bethnal Green, carry these things home, and when they have in this way, or by independent foraging for them, accumulated a sufficient quantity, proceed to burn them in order to extract the solder, for which they can obtain about 5*d.* per lb., the burned iron selling for scrap-iron afterwards for about 3*d.* per cwt. The method of burning consists almost universally in building up a large heap of these things, alternating with them layers of wood shavings. The shavings are ignited, and, when they are all burned out, the iron is removed and the ashes are collected and washed in an iron dish for the recovery of the solder found among them. Some persons who can afford it, while they burn the larger articles in this way, burn the smaller ones in an enclosed brick furnace, the smoke being conducted away to a low chimney.

Nuisance.

Beside the smoke emitted thus in large volumes at a low level, there is accompanying it a most offensive irritating vapour, due to the burning of the paint with which such articles as I have mentioned are commonly covered. The smell travels a long distance. I have myself perceived it offensively in a main street at a distance of 100 yards from the place where burning was going on in some yard or close court somewhere at the rear. Respectable residents in the neighbourhood have complained a good deal of the nuisance, and have said that the smell enters their houses and makes them feel ill and depressed, and gives them a sensation as if they wanted air.

I understand that the Vestry of Bethnal Green has scarcely known how to deal with this nuisance, apparently on account of the poverty of of the people who make it; but some years ago they served notices on them to do all their burnings at night, and thus to reduce so far as was considered practicable the nuisance occasioned to their neighbours. There can be no difficulty in saying how the nuisance might be abated, namely, by burning in a close furnace and by washing the smoke, and then passing the washed smoke through a fire; but such requirements would result in prohibiting the trade to persons who could not afford to erect the furnace and washer.

THE CALCINATION OF ARSENICAL ORES AND REFINING OF ARSENIC.

Establishments visited.

Establishments Visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 23, 1877	English Arsenic Company.	Camborne.	—
„ 24, „ -	Evans - -	Blown-house Valley, Redruth.	Dressing tin ores.
„ „ „ -	Tincroft Mine -	Poole.	—
„ „ „ -	Carn Brea Mine -	Ditto.	—
„ 26, „ -	Several "burning-houses."	Tucking Mill, Redruth.	—
„ 27, „ -	Wheal Gilbert Coombe.	Tolgus Valley, Redruth.	—
28, „ -	John Paynter -	Bisso Bridge -	Manufacture of sulphuric and artificial manures.
„ 30, „ -	Devon Great Consols.	Tavistock.	—
July 25, 1879	Cornwall Arsenic Company.	Hayle.	—
„ 26, „ -	Do.	Bisso Bridge.	—
„ 30, „ -	Okel Tor Arsenic Works.	Calstock.	—

Arsenical ores used.

Arsenious acid is obtained by the calcination of various arsenical ores, the most common of which are the arsenical tin and copper ores of Cornwall and Devonshire. These contain arsenic in the form of arsenical pyrites ($Fe\,As + Fe\,S^2$), a compound of arsenide and bisulphide of iron. Hence it is common to see the manufacture of arsenious acid forming part of the first process to which the tin ores are subjected to in West Cornwall, and the copper ores in East Cornwall. The quantity of arsenic in the tin ores raised in Cornwall and dressed there, either at the mines or on the streams which carry down tin ore from the hills ("stream tin"), varies greatly, so that at some works the arrangements for collecting arsenious acid are on a much more extensive scale than they are at others. The process is similar whether it be a cupreous or a stannous ore that is dealt with.

Process of calcination.

The ore, first stamped and dressed by what is termed "buddling" (a wet process for the separation of the metallic matter from the gangue), is subjected to a process of calcination, the object of which is to burn off the arsenic as arsenious acid, and the sulphur as sulphurous acid, and to peroxidise the iron. Three methods of doing this are commonly in use in Cornwall. One of these is by burning the ore in a reverberatory furnace with a flat bed, on which the ore in the state of powder is subjected to a dull red heat for about 24 hours, during which it is frequently turned over. When believed to be sufficiently burned, it is raked out, either on to a floor or a hearth prepared to receive it. The material is again buddled, and the product of the washing is again calcined for about 12 hours, this time with a stronger heat. In many instances one calcination is found to suffice. This method is called "hand-calcining." If the heat be too great at the first calcination, or if the material have been introduced not sufficiently dry and powdery, and if it be not kept well stirred, it is apt to cake, and then the centre of the caked masses is apt to be insufficiently burned. Hence the operation requires constant careful watching. Another apparatus largely

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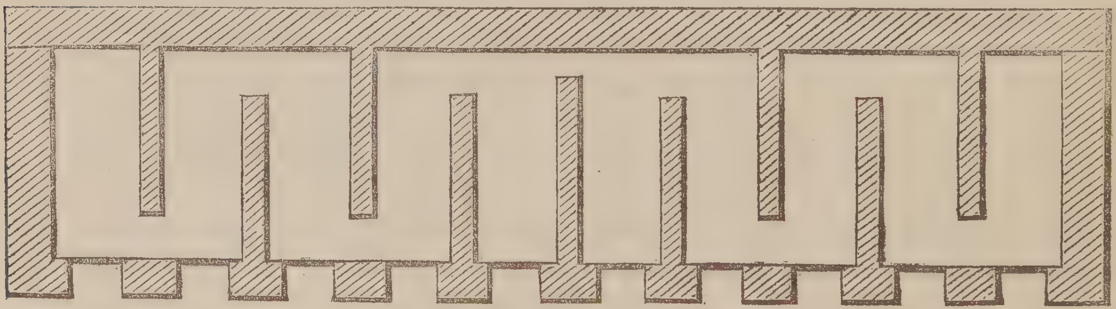
used in Cornwall is "Brunton's calciner." It is essentially a circular reverberatory furnace, the floor or bed of which, made of firebrick laid on a slightly curved tàble of iron, revolves slowly. Numerous iron scrapers or ploughs project down from the roof nearly to the bed, and are so constructed as to turn the powder over and to move it a little outwards on the floor as it revolves. The ore fed in at the middle of the roof is in this way made to travel slowly towards the edge, and at last to fall into a box or "wrinkle" prepared for its reception. A portion of ore takes from six to eight hours to travel thus to the edge. The calciner is heated by two fires placed as near as convenient to each other opposite the uptake through which the gases escape. It is said that this calciner is best adapted for stamped ores, stream material (ore washed down in the streams) being too fine to be dealt with in this way. The third kind of calciner in use in Cornwall is the patent of Oxland and Hocking. It consists of a wrought-iron cylinder 20 to 30 feet long, with an internal diameter of from 3 feet to 4 feet 6 inches, and lined with firebrick. It is mounted in an inclined position and caused by machinery to revolve slowly, and the ore fed in at the upper end is turned over and over as it flows slowly towards the lower end, where it is discharged. The turning over of the ore, so as to expose all parts of it to the heat, is effected by four longitudinal ribs of firebrick, which project into the interior. The flame from a furnace enters at the lower end, and the products of combustion and calcination pass away by a flue from the elevated end. A fourth mode of burning a highly sulphurous arsenical ore, I saw in use at only one establishment. The ore containing, it was said, as much as 30 per cent. of sulphur—at any rate enough to burn by itself without fuel—was calcined in kilns built like the limekilns used for continuous burning, but covered in at the top where the ore was charged in through hoppers provided each with a damper to close the bottom of it. The arsenious and sulphurous fumes were carried off from the upper part of the kiln by flues. The process was a very imperfect one.

Mode of collecting arsenious acid.

With a view to collect the arsenious acid, one or more chambers are constructed in the course of the flue (which itself is usually capacious) to the chimney shaft. The chamber may vary in height from 7 to 12 feet, and is provided with a number of vertical partitions, springing alternately from opposite sides or ends of the chamber, so as to constitute the chamber a series of zig-zag passages from 3 to 4 feet wide and from 8 or 10 to 40 feet long. Each passage or section in the ziz-zag is provided with an iron door, by which a workman enters it at due intervals to remove the deposited arsenic, but which at other times is closely luted up. From the chamber the flue usually proceeds either straight or

FIG. 38.



SCALE $\frac{1}{16}$ IN. = 1 FT.

angularly, and when feasible up a hill-side, to the chimney-shaft. Fig. 38 is a plan of one of these ziz-zag chambers attached to the refinery at the works of the Devon Great Consols. It is 6 feet high, but there

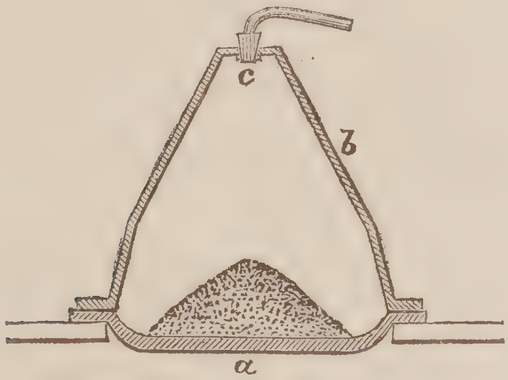
are other chambers longer and higher. From the chambers at this work a capacious flue passes with angular bendings for 150 yards up a hill to the chimney-stack, 120 feet high, the base of which is 80 feet above the level of the works. Other works I visited had chambers much longer. For instance, at the burning-houses in the Tucking Mill Valley there is a zig-zag chamber containing 18 passages, each 33 feet long and 7 feet high by 4 feet wide, and at the East Pool "burning-house," close to it, there are no less than 400 yards and more, mostly of similar zig-zag, 10 or 12 feet high, between the calciners and the chimney. The flues are also in all cases provided with doors at convenient distances when they are above ground, as they usually are; but sometimes they are constructed under ground, and then they have to be opened above to gain access to the interior of them.

If the flues be duly tight, all the sulphurous acid from the combustion of the ore not condensed with the watery vapour in the flues (and this is probably only a small proportion of the whole) escapes into the air by the chimney, and with it so much of the arsenious acid passes off as the flues have failed to arrest. In works where the ore is more sulphurous than arsenical, but little pains are sometimes taken to collect the arsenic, and then the larger proportion of it goes off by the chimney with the sulphurous acid.

Refining arsenious acid.

The arsenious acid taken from the flues and zig-zags of the burning-houses is more or less crystalline, and mixed with sooty matters and also with some moisture which is acid from the oxidation of the sulphur of the ores; it has therefore to be refined. For this purpose a reverboratory furnace is again used, with a flat, square, or oblong floor, and smaller than the furnace used for hand-calcining. The fuel used is mostly coke, and sometimes a second fire is used, the flue from which is made to pass beneath the floor of the oven to heat it beneath. The volatilised arsenic is collected in zig-zags as before. Such refined arsenic is powdery: when lump or vitreous arsenious acid is to be made the arrangement adopted is of a different character. There are two forms of apparatus in use for this purpose. In the one form, Fig. 39, a strong circular cast-iron dish *a*, about 2 feet wide, is provided, which

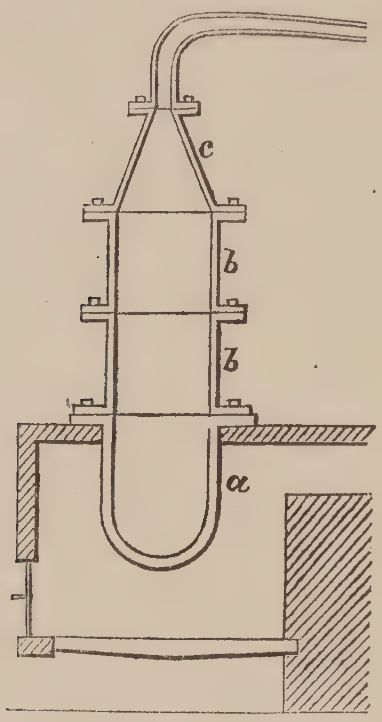
Fig. 39.



is supported by the flange over a fire; on this is placed a conical iron cover *b*, termed the "kettle," and the flange of the kettle is closely fitted to that of the dish by wedges. At the summit of the cone is a hole about two inches wide, which, during the sublimation of the arsenic, is closed by a stopper *c* having a handle. A pair of these dishes are placed, so as to be heated by one fire, in a sort of closet terminating above in a low chimney and enclosed in front by an iron door, so that any arsenious acid that may escape shall not pass into the room, and so injure the workmen. The charging is effected in portions thus: the

kettle being wedged on, a quantity of crude arsenious acid is introduced by a funnel into the hole at the top, and falling down forms a little conical heap in the centre of the dish. A similar fresh charge is introduced about every two hours, and at the end of about 24 hours the fire is put out and the kettle removed, when the vitreous arsenic is found coating its interior, and is chipped out. The interior of the closet and chimney at the works where I saw this process followed was coated with powdery arsenious acid. Judging from appearances about the

Fig. 40.



closet door, I am not at all satisfied that no arsenic escaped into the apartment. The other form of apparatus is indicated by Fig. 40. It consists of four flanged pieces bolted together by their flanges. The lowermost is a strong cast-iron pot *a*, about 2 feet deep and about 18 inches wide, heated by a fire beneath and all round. Above this are two cylindrical pieces *b b*, rising above the pot to a height of about 3 feet, and surmounting these a conical piece *c*, from the summit of which a 3-inch pipe conveys any uncondensed matters into a zigzag chamber. The charge is all introduced at once, and the process of volatilisation is said to be completed in about four hours. The fire is then put out, and the apparatus is allowed to cool; the vitreous arsenious acid is found lining the three top pieces. Whatever escapes condensation in the apparatus is passed into the zigzag, and not as in the other form of apparatus into the air.

Nuisance.

During my inquiries in Cornwall I heard and saw a good deal of the injury done to vegetation, and especially to trees and shrubs, by the fumes from the "burning-houses," (as the buildings where the calcination is done are termed), and also something of the injury done to horses and cattle by the deposition of arsenical fumes upon grass fields in the vicinity of such works. But of these complaints I only took casual notice. The points which concerned me most were the offensiveness of the fumes and their effect upon the health of the population. When the fumes are, as is the case at some works, carried in tight flues up a hill-side, and discharged from the top of a tall chimney, or where the works are situated in a wild uninhabited part of the country, no offence is occasioned by the fumes so discharged; but in some cases where carelessness or bad arrangements of the flues and

chimney prevail, the nuisance from the fumes is very considerable. This I noticed to be especially the case where the burning-houses were situated at the bottom of a narrow valley, and the chimney tops were not higher than the level of the head of the valley, a little way off, where the population chiefly resided. In such cases as these the sulphurous acid fumes wafted up the valley gave rise to much, and I am assured, well-founded complaint of annoyance. They are suffocating, and occasion cough and dyspnœa, and are especially distressing to persons suffering from pulmonary complaints. Although the people who work in the burning-houses and refineries suffer from the fumes, which produce in them gastric disturbances in some cases, bronchial and laryngeal irritation in other cases, and (and this appears more common) an eruption (known among the workpeople as "burning-house pox,") about the genitals and on exposed parts of the body, especially at the flexures, I have not been able to discover, by inquiry of the medical men practising in the districts affected, that any disturbance of health that could be believed due to the operation of arsenic had occurred within their experience among the people exposed outside the works to the influence of the fumes. This was their experience even where the water drunk by the population was rain water, which had, in its descent, washed the air.

Injury to health.

Source of nuisance.

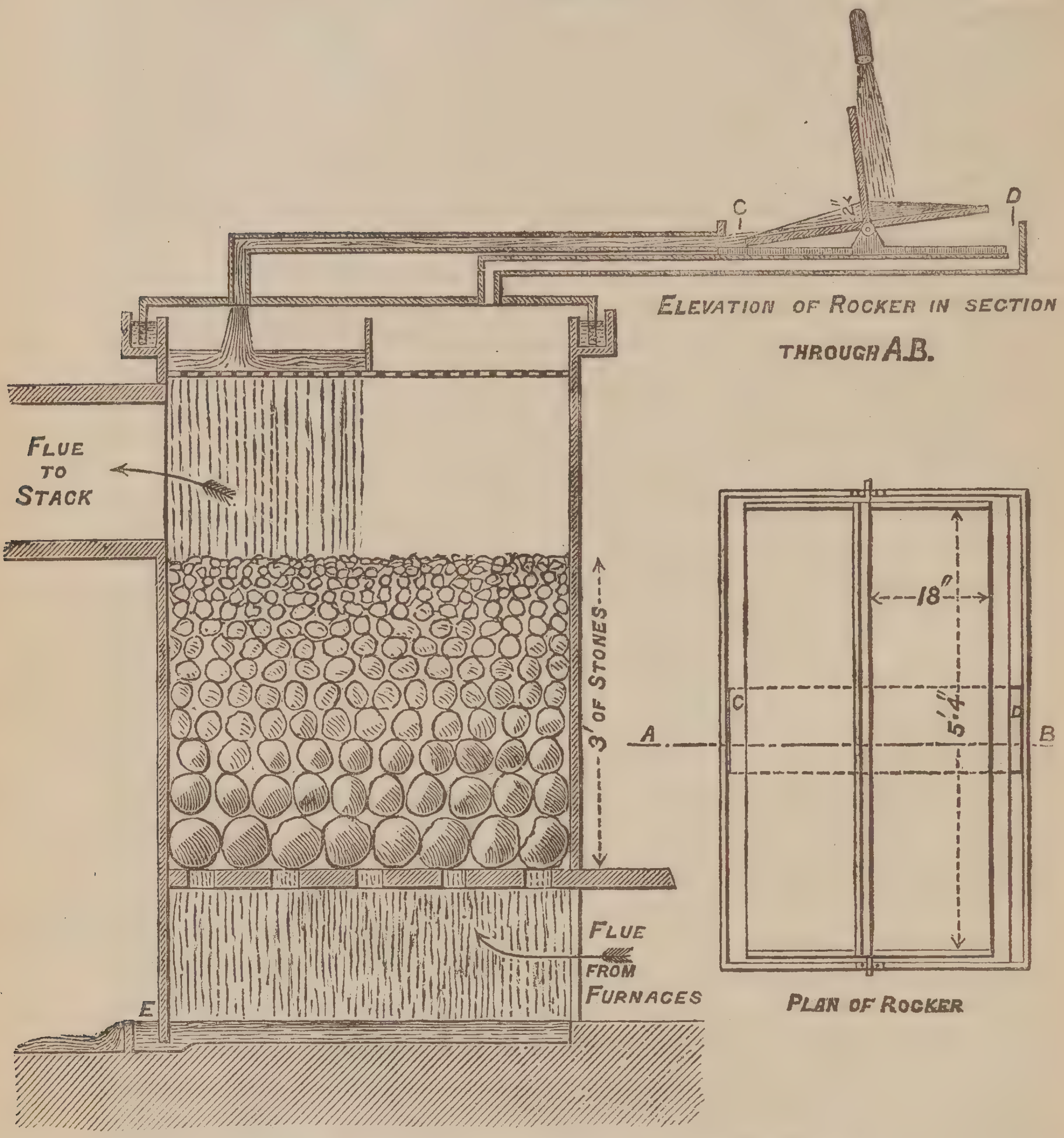
The chief source of the nuisance, of course, is the discharge of the sulphurous acid from the chimneys of the burning-houses, but there are other minor conditions which may assist in occasioning nuisance. One of these is the drawing of the ore from the calciner before it has been thoroughly calcined. One mode in which this may arise has been already pointed out (p. 253). Another is leakages from the flues. Indeed, I am wrong in terming this a minor source of nuisance. In one instance I met with, it was the main cause of a very great nuisance at a place close to Redruth, where the flue from a burning-house in the Tolgus Valley crossed a main road in its ascent up a hill side to a low chimney at the top of the hill. It was here a very great annoyance to persons travelling along the road, as well as to persons residing near the flue. This was a case where the flue was in part subterraneous, and where openings had to be made in its roof to clear it of deposit.

Prevention of nuisance.

Where practicable, the uncondensed fumes should be discharged at such an elevation and at such a distance from inhabited houses that they shall be thoroughly dispersed before they have time to fall in such quantities as to occasion nuisance. But where this is not practicable it is by no means easy to say what should be done. Sulphurous acid once mixed with a large volume of air is one of the most difficult things to condense, and the acid given off from the calciners is thus largely diluted. This is not the only instance in which a similar puzzle is presented for solution. I shall have occasion to allude to it, for example, when considering the nuisances from copper smelting. At the Devon Great Consols, where arsenical mundic is calcined, there is interposed in the course of each of two large flues which join the main flue to the chimney shaft, and near the top of the hill, a "tip-jack" washer, the object of which is to wash out the last portion of the arsenious acid. It also acts by taking out some of the sulphurous acid, how much I cannot tell. Mr. Richards, the manager, says it does not interfere with the draught of the calciners, but on the day that I visited the works, the draught from one of the reverberatory calciners was interfered with by something, since I perceived in the workshop a pretty strong odour of metallic arsenic, which could only have issued from the calciner. At these works, in order to improve the draught when requisite (but this might have been to obviate occasional increased coldness of the chimney), a fireplace is provided at the foot of the chimney shaft. I am afraid, too, that the practice

of washing the fume is not calculated to do the chimney any good. The washers had been in operation for 10 years, and the chimney showed by stains on all sides evidence of the passage of liquor through it. A plan of the washer and rocker or tip-jack is given in Fig. 41. The

Fig. 41.



washer is filled with round stones and the water is cast by the rocker first on one side, then on the other, according as the water is discharged into the opening *c* or *d*. The rocker discharged about 3 gallons of water per minute. In addition to the above apparatus, with a view to obtaining a further condensation of the waste gases, two capacious condensers, each 12 feet square and 30 feet deep, have been constructed between the rocker and the chimney shaft. They are shower chambers in which water falls from a perforated cistern at the top upon woodwork within, so arranged as to break up and distribute the water as it falls through. The gases pass down the first condenser and up the second.

At Paynter's works at Bisso Bridge, where several kinds of mundic and tin ore are calcined, one kind is calcined in a muffle or oven, and the sulphurous acid formed is carried to a vitriol chamber and made into sulphuric acid. The ore which was being thus treated was found by

my son, Mr. E. G. Ballard, to contain 22·2 per cent. of sulphur, and the calcined stuff 3·8 per cent. Few of the ores of the district, however, could be treated in this way, on account of the large quantity of air that has to be admitted to oxidise the arsenic where this is abundant. The dressed and buddled arsenical ores which my son examined for me contained from 1·0 and 1·5 per cent. of sulphur in the Carn Brea ore, and 1·8 per cent. in the Tin Croft ore, to 13 per cent. in the ore which was being calcined at Evans' dressing works near Redruth.

It appears reasonable to suppose that ores containing sulphur enough to burn without fuel might be calcined in an ordinary pyrites burner or otherwise, and the sulphurous acid, after the arsenious acid has been deposited, might be utilised for sulphuric acid making. But without due care a nuisance might even thus be created.

Flues exposed above ground to variations of temperature require constant attention and repairs to obviate leakage. Still they are best above ground, since they can be conveniently got at, but they should be covered over with a layer of earth and sods, except in places where the doors are situated, as they are at various works I have visited. The occasional nuisance from drawing a charge from the calciner before the charge is fully calcined, and while it is still capable of giving off fumes, may be obviated by care and by drawing the charge into a covered pit.

COPPER-SMELTING.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Feb. 29, 1876 -	Newton, Keates, & Co.	St. Helen's, Lanc.	Manufacture of sulphuric acid, artificial manures, &c.
Jan. 3, 1879 -	Hafod Copper Works (Vivian's).	Swansea -	Manufacture of sulphuric acid, artificial manures, &c.
„ 6, „ -	Middle Bank Copper Works (Grenfell's).	Ditto.	—
„ 8, „ -	Port Tennant Copper Works (Lambert's).	Ditto.	—
„ 10, „ -	Neville, Druce, & Co.	Llanelly.	—
Feb. 24 „ -	Newton, Keates, & Co.	St. Helen's, Lancashire.	(Second visit.)
„ 25 „ -	St. Helen's Copper Company.	Ditto - -	Manufacture of sulphuric acid.
„ „ „ -	Bibby & Co. -	Ditto.	—
„ „ „ -	Baxter -	Ditto.	—

Ores of copper.

The common ores of copper smelted in this country are essentially sulphides of copper. But other kinds of ore are received at copper works and smelted with these ores, namely, carbonates and silicates; but it must be understood at once that these latter ores are never smelted alone, a sulphide being always mixed with them at some stage of the process. Hence, inasmuch as it will appear in the sequel that the principal nuisance of copper smelting is connected with the separation of sulphur, it will conduce to simplicity and suffice for the purpose of this Report, to describe briefly the mode in which the sulphide ores are

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dealt with in South Wales and other places in England for the extraction of copper by the dry way. Before doing this, however, it is necessary to add that, beside copper ores in the raw state, ores which have undergone some previous preparation abroad, such as what is termed Chili regulus, or Chili bars of "coarse metal," are received at copper works, and also ores which have been previously calcined in this country, such as the ores rich in sulphur but poor in copper, which are used commonly in the manufacture of sulphuric acid (p. 169): precipitates from wet processes of extraction (p. 270) are also commonly received and dealt with.

For the purposes of this Report I may divide the sulphide ores into,—

(*a.*) Ores rich in sulphur but not in copper, such as the Tharsis ores.
(*b.*) Ores comparatively poor in sulphur, such as are ordinarily smelted in the dry copper works in England.

The former ores contain as much as 46 or 48 per cent. of sulphur, and only from 2 to 5 per cent. of copper. In the latter the quantity of sulphur varies from 10 to 30 per cent., while the copper varies from 3 to 35 per cent.

The sulphur in the ore is combined with copper and iron. Arsenic is also present in certain ores. Other metals, which it is worth while to extract, such as silver and gold, are also contained in the ores treated. The gangue or matrix of the ore, present in variable proportion, consists mainly of siliceous matters. The copper regulus imported from abroad has undergone a first calcination and fusion to free it from the earthy matter originally contained in the ore. It consists mainly of copper and iron in combination with sulphur. In other words, it may be called a "concentrated" ore.

The poor copper ores rich in sulphur are generally used for the manufacture of sulphuric acid, and, after having been burned or calcined at sulphuric acid works (*see* Sulphuric acid making), the burned ore is now usually treated in the wet way, for extraction of the copper and other metals it contains. But some of these burned ores are occasionally smelted in dry copper works, being useful to mix with rich ores.

Process of smelting.

I will first describe the method of smelting as practised at Swansea. The description may not be easy to follow, but will be perhaps rendered more easy of comprehension by referring to the accompanying scheme (No. 1) of the process (with the exception of the last process—"refining") as carried out at Mr. Vivian's Hafod Works, and to another scheme of the process (No. 2) as carried out at the Middle Bank Works at Swansea, for which latter scheme I am indebted to Mr. F. S. Bishop, of those works. The former is the simpler of the two, since one operation, namely, the production of "blue metal" and its subsequent conversion into "white metal" is dispensed with.

Briefly, the method of smelting consists in alternate processes of "calcining" and "melting," until the iron has become separated, and a nearly pure sulphide of copper has been obtained, from which the sulphur is burned off by what is termed "roasting," metallic copper being left, which has only then to be "refined" to become the copper of commerce. Instead of describing each of these steps as a distinct process, it will assist their comprehension if I describe the processes in groups thus:—

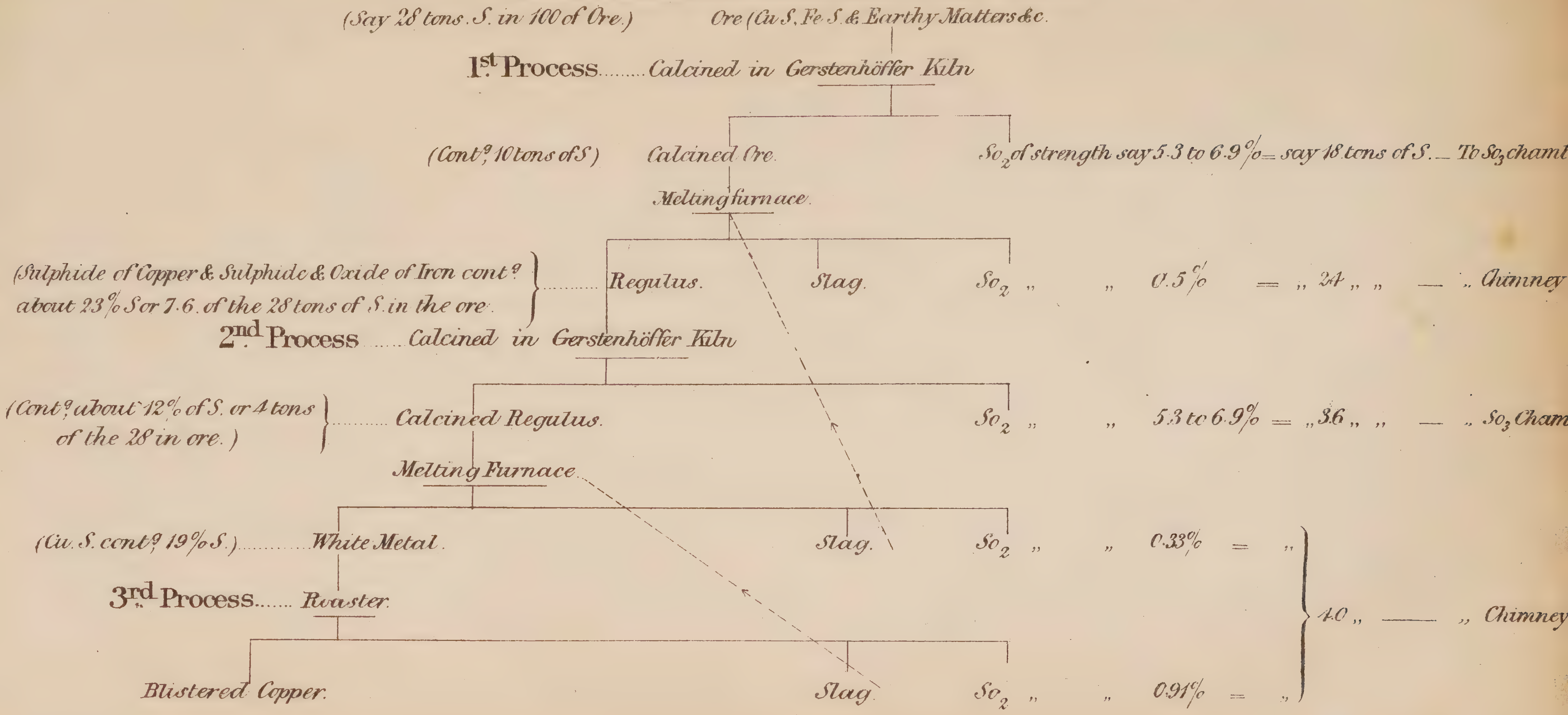
First process.

First Process.—*a.* Calcination, and *b.* Subsequent melting of the ore for the production of a "regulus" or "matte," commonly termed "*coarse metal.*"

Calcination.

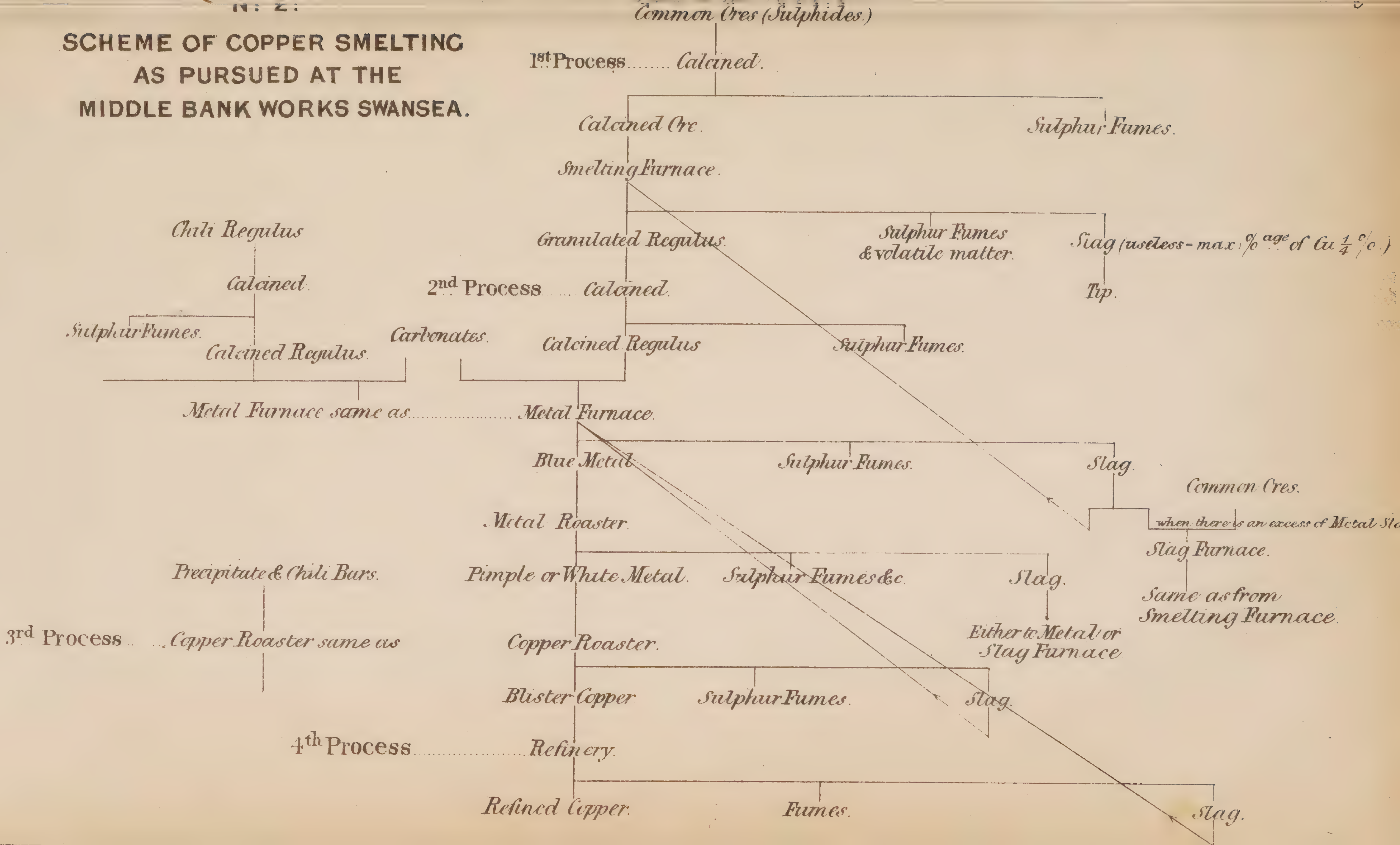
a. Calcination.—Finely crushed and disintegrated ore is introduced into a "calciner," which is a reverberatory furnace, where the ore is exposed

SCHEME OF COPPER SMELTING AS PURSUED AT MR. VIVIAN'S COPPER WORKS, SHEWING THEORETICALLY HOW THE SULPHUR IS DISPOSED OF.



DANCERFIELD. LITH 22. BEDFORD ST. COVENT GARDEN.

SCHEME OF COPPER SMELTING AS PURSUED AT THE MIDDLE BANK WORKS SWANSEA.



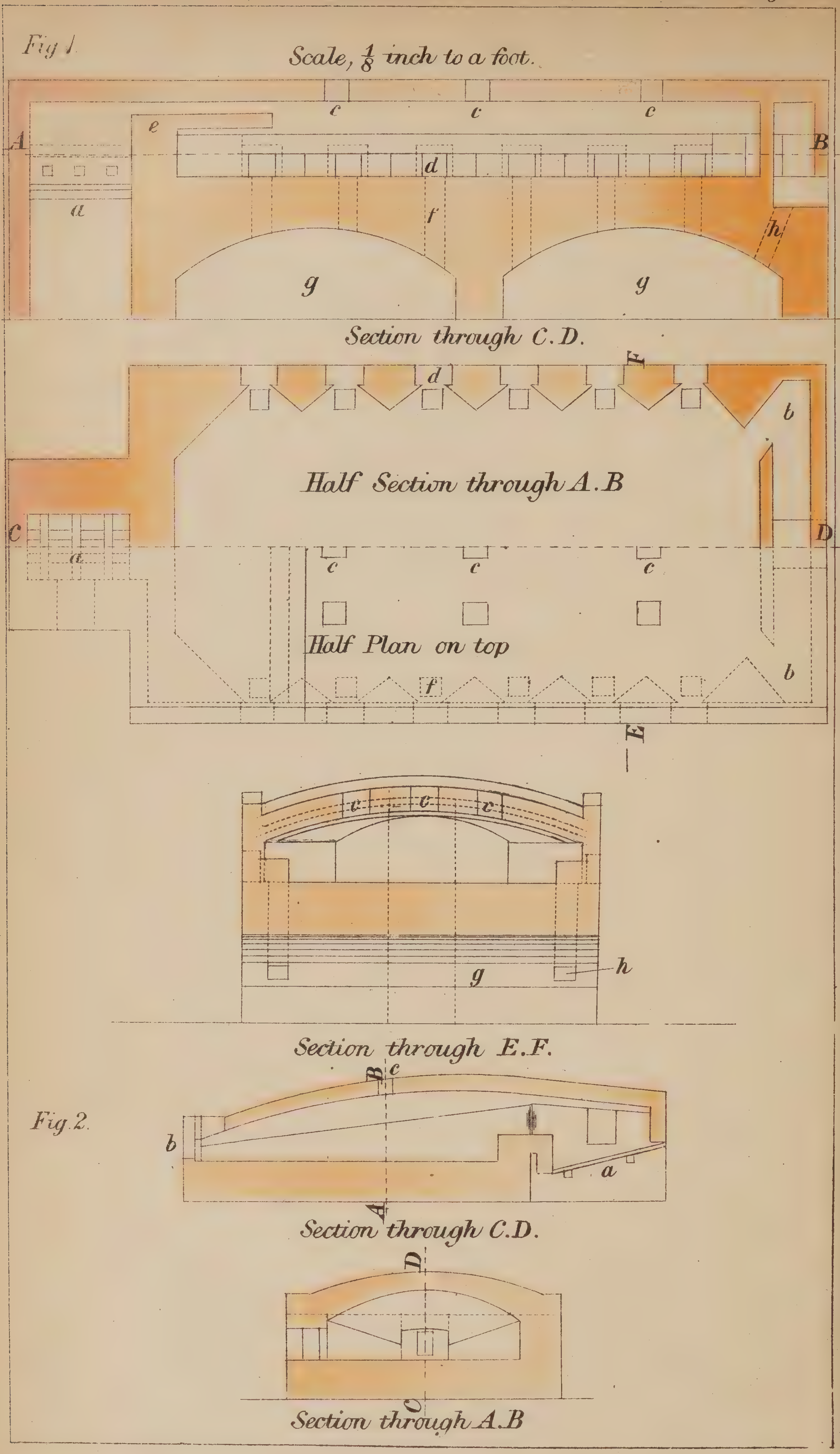


Fig 1.
Scale, $\frac{1}{8}$ inch to a foot.
Section through C.D.
Half Section through A.B
Half Plan on top
Section through E.F.
Fig. 2.
Section through C.D.
Section through A.B

to the moderate action of the flame of a fire playing over the top of the ore. Calciners are of various kinds. Plate XXVII., Fig. 1, represents in plan and section the essential points in a calciner such as is in use at the Hafod Works. It may suffice for my purpose. It is a long flat-bottomed chamber with a low arched roof, having a fire *a* at one end, and flue openings *b* at the other end. At intervals in the roof are openings *c*, provided with appropriate means of closure, through hoppers attached to which the ore is charged. At due intervals along each side there are openings *d* with proper covers, through which openings the workman introduces a tool or "rabble" in order to turn about the ore, and to move it from the cooler to the hotter part of the calciner nearer the grate as the calcination progresses and greater heat is desired. The bridge *e* is constructed with an arch projecting into the calciner for a distance of some feet, the object of which is to protect the ore lying nearest to the grate from the too intense heat of the flame. Near the side doors are square openings in the floor, closed during the calcination with appropriate movable covers; when the calcination is finished, these covers are removed, and the calcined ore is raked through the openings into open vaulted chambers *g* below, which chambers are commonly provided with iron doors to close them in and prevent the escape of fume from them into the works, and also with a flue *h* (capable of closure with a damper) leading to the flue of the calciner, to carry off the fume from the chamber. In this process much of the sulphide of iron and some of the sulphide of copper are converted into oxides, sulphur and arsenic being oxidised at the same time; the volatile matters formed (about which I shall speak presently) being, with dusty matters and the products of combustion of the coal, discharged into the flue.

Melting.

b. Melting the calcined Ore.—The calcined ore is now transferred to the smelting furnace, where it is melted down, sometimes with an admixture of ores low in sulphur, which it has not been therefore necessary to calcine, resulting in the production of a regulus or coarse metal and a slag. Fig. 2 of Plate XXVII. represents the essential points of construction of an ordinary smelting furnace. It is again a reverberatory furnace smaller in area than an ordinary calciner, and having no side doors, but merely a tap hole for the metal on one side, towards which the bed or floor, which is oval and wider near the fire *a* than at the further end, is made to incline so as to form there a sort of basin. At the end opposite the fire is an outlet *b* by which the slag is raked out. The charge is introduced through a hopper at an opening *c* in the roof. The heat applied in this process is sufficient to fuse the charge, the fusion being completed in the course of about six hours, when the slag is skimmed out into sand moulds previously prepared for its reception; and the processes of charging, melting, and skimming out of the slag are repeated until coarse metal enough has accumulated to fill the bed of the furnace. When this is the case the tap-hole is carefully opened and the metal (or regulus) is run out. Ordinarily it is run out in a jet into a tank of cold water, by which it is granulated or coarsely divided into little irregular grains, each of which has a somewhat polished appearance on the surface. In this process the oxide of iron combines with the silica present to form a very fusible silicate of iron, which is the main element of the slag, and so much of the iron as is thus combined is removed from the ore under treatment.

The "regulus," "coarse metal," or "ore-furnace metal" formed is essentially a sulphide of copper with some sulphide of iron. It contains about 23 per cent. of sulphur. A little regulus which has been drawn

out with the slag is removed by chipping, and then the slag (ore-furnace slag) is carried off to the tip, and thrown away. Volatile matters resulting from oxidation of sulphur, &c., are discharged with the products of combustion by the flue.

Second process.

Second Process.—*a.* Calcination, and *b.* Subsequent melting of the "regulus" or "coarse or ore-furnace metal" for the production of "*blue metal*," or "*white metal*," as the case may be; the blue metal being only an intermediate stage between the regulus and white metal—a stage which in some works is omitted, the regulus being, first by calcination and then by melting, at once converted into white metal.

Calcination.

a. Calcination.—The regulus or coarse metal is in its granulated condition introduced again into a calciner in all essential points like that used for calcining the ore. The object of the calcination also is the same, namely, to oxidise sulphur and iron still present in an unoxidised condition. The charge is frequently and carefully rabbled in order to ensure the thoroughness of the operation.

Melting.

b. Melting.—This is performed in a furnace similar in most respects to the melting furnace for calcined ore, but without a hollow in the floor, only an inclination of it towards the tap hole. The slag is raked out into sand moulds by which it is formed into pigs, and the metal is run out into pigs. The slag known as "metal slag" (essentially again silicate of iron), contains about 2 per cent. of copper, and is not thrown away, but is mixed with charges of the first melting furnace (that for coarse metal). The white metal contains about 19 per cent. of sulphur.

Third process.—Roasting.

Third Process.—Calcining is now all over, white or blue metal being now to be dealt with. White metal consists of almost pure sulphide of copper, while blue metal contains in addition a proportion of iron. The third process now to be described is termed "*roasting.*" It is in fact a third melting process, but with free access of air, the object being to burn off the sulphur, slagging off at the same time what iron there may still be present. The furnace employed is similar to that used in the melting of the calcined regulus, except that there are passages provided for the admission of air near the bridge. The metal is introduced in masses at a side door with which the furnace is provided, and piled up on the floor of the furnace. After a time it begins to melt and drip, and when it is all melted the slag is skimmed off into moulds, and the heat continued until it is believed that all the sulphur is burned off, when the metal is drawn off by the tap-hole into sand moulds. This metal, which is known as "blister-copper," contains from 93 to 96 per cent. of copper, with only a little sulphide and oxide. The slag is known as "roaster slag," and is mixed with charges of the second melting process, so as to recover the copper it contains. The sulphurous acid formed passes away by the flue.

Fourth process.—Refining.

Fourth Process.—*Refining.*—This consists in a second roasting in a reverberatory furnace, the object being to oxidise any remaining sulphur, to slag off adhering impurities, and to bring the copper to "tough pitch" if destined for rolling, or into "fine ingot copper" if destined for brass making. The scoriæ being raked off, the copper is found to be brittle when cold; this brittleness being due to the presence of a suboxide diffused through the copper. To reduce this and soften the metal, ground charcoal or anthracite coal is scattered over the molten surface, and the metal is stirred with a pole of wood. This process is called "poleing." Refining is a delicate operation, and its progress has to be tested from time to time by taking out and examining samples of the metal: but it has no special interest with reference to this Report.

"Copper smoke.

The part which sulphur plays throughout this process is to be

remarked. Through every stage of the process it is being removed by oxidation. In the earlier stages, the sulphur combined with the iron in the material dealt with is being chiefly burned off, and in the roasting process the sulphur combined with the copper is burned off. Other things are oxidised, such as arsenic, which is converted into arsenious acid, and iron, which is converted into an oxide which slags off with silica. The volatile matters which come off and find their way into the flues, and ultimately (even more or less under the best arrangements to prevent it) into the open air, are all the sulphur oxidised into sulphurous acid and sulphuric acid (the latter in part combined with oxide of copper as sulphate of copper), arsenious acid, fluoride of silicon when fluor spar is present, dust from the calciners, &c., and the products of combustion of the fuel. It is the mixture of these volatile and dusty matters which, passing out from the chimneys of copper works, goes under the familiar designation of "copper smoke." In 1854 the late Dr. Thomas Williams, of Swansea, published in the form of a pamphlet the results of some observations as to copper smoke which he had undertaken at the suggestion of the General Board of Health. He found that, although arsenic is undoubtedly one of the elements of copper smoke, not the slightest indications of its presence in the smoke were discoverable, chemically, at a distance of 200 yards from chimneys emitting it. By washing the air in places very near the works at a time when the smoke is thickest, he says he has repeatedly succeeded in demonstrating the presence of copper, but that he found it impossible to detect it in the diluted smoke at a distance exceeding a few yards. But, on the other hand, a copper smelter, whose statement in the matter is trustworthy, told me that he had found copper on the surface of snow at a distance of three miles from his or any other copper works, and that, after skating last winter upon ice at a distance of one mile from his works, he had found copper deposited upon the steel of his skates. I am informed that few ores containing fluor spar are now smelted in Swansea. Where this constituent is wanting or not used as a flux, there can of course be no fluoride of silicon in the smoke.

Nuisance from copper-smoke.

The nuisance occasioned by the volumes of copper smoke habitually poured forth into the air from dry copper works, especially when such works are situated, as they mostly are at Swansea, in a narrow valley, and from low chimneys, has been made the subject of a good deal of sensational writing, containing a great deal of truth, and no small amount of exaggeration. I have here nothing to say about the effect of the fume upon vegetation exposed to it habitually; this is a branch of the subject investigated by the Select Committee of the House of Lords on Lord Derby's Bill in 1862, and more fully by the Royal Commission on Noxious Vapours, which made its Report last year. I shall confine myself to its effects upon the population. These effects cannot be studied under conditions more simple than exist at Swansea and its neighbourhood, inasmuch as by far the greater part of the smoke which obscures the valley in which the Hafod and other copper works lie, issues from these works. There is here less complication of the question than at St. Helens, since, with the exception of one small alkali work and one manure work, the other works in this valley are lead works, nickel works, spelter works, and tin-plate works, all of which except the last-mentioned give issue to similar fumes of sulphurous acid and arsenical vapours.

Effect upon health.

The copper smoke which is, in some conditions of the weather, thick enough to intercept vision across the valley, is decidedly disagreeable to strangers, although not complained of by the inhabitants of the valley and of the sides of the hills which border it—persons who for the most part

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are dependent for their living upon the works which create the smoke. It is sometimes complained of, but never with any urgency, by persons residing in Swansea, whose houses the smoke reaches in certain directions of the wind. It is acid to the smell and taste, and is said sometimes to have a metallic taste in addition—a circumstance which may be due to the presence of copper in it. I cannot say I have ever perceived this metallic taste myself. I have heard it said that it produces a sense of oppression of breathing when reaching persons in a less diffused form than is customary. Probably what Dr. Thomas Williams, in the pamphlet before referred to, says about it, may be accepted as fairly correct. "There are occasions, undoubtedly, on which the presence of the "copper smoke over the town of Swansea is disagreeably perceptible to "many individuals. * * * On such occasions it produces decided "effects upon the vast majority of the inhabitants. They consist most "generally of a dry sensation in the throat, a tight feeling across the "chest, sneezing, watering and smarting of the eyes, &c. In those "whose bronchial membrane is already irritable, a slight expectoration "is excited. These effects are chiefly felt on first going from the house "into the air in the morning and in the evening. They are not "perceived in the middle of the day. They last, under the worst "circumstances, only for a few minutes." There is, however, no very definite proof that it injures obviously the health of persons habitually exposed to it. Mr. Ebenezer Davies, the Medical Officer of Swansea, has taken a good deal of trouble to determine this point for me by an analysis of the mortality statistics of the urban district of Swansea. And although these statistics are open, as all such methods of determining such a question must necessarily be, to much damaging criticism, I cannot, in justice to him and to the copper smelters, abstain from giving his results. He divides his urban district into three parts, viz., Swansea proper, including the town of Swansea, with an estimated population in 1877 of 46,419 ; Clase and St. John, with a population of 13,819 ; and Llansamlet, with a population of 3,059. During the five years estimated, 1872 to 1876 inclusive, and calculating the mortality upon the estimated mean population of those years, he obtained the following results :—

——	Total Deaths.	Deaths under One Year.	Deaths from seven Zymotic Diseases.
Swansea - - -	24·2	6·3	4·1
Clase and St. John -	20·7	6·0	3·5
Llansamlet - -	18·3	6·2	2·3

In the other figures he has given me, the deaths are calculated as a per-centage upon the total deaths for the four years 1874 to 1877 inclusive.

——	From Phthisis.	From Croup.	From Bronchitis, Pneumonia, and Pleurisy.	From Bronchitis.
			At all ages.	Under 5 years.
Swansea - - -	9·4	1·2	17·0	8·2
Clase and St. John -	9·0	1·9	15·7	9·2
Llansamlet - -	9·5	2·5	20·0	8·3

These figures were calculated in order to discover whether the parts of his district most exposed to copper smoke suffered from a higher mortality generally, or from certain specified forms of diseases, more than the parts less exposed to it. Swansea, as I mentioned before, is certainly least exposed to the influence of the copper smoke, whereas the Hafod Works, the most extensive in the valley, are actually in the parish of St. John, and the districts of Clase and St. John and of Llansamlet, the one lying to the west (mainly on the hill side) and the other on the hill side to the east of the valley, are exposed almost constantly to the fume which sweeps around the houses, sometimes more on one side and sometimes more on the other side of the valley according to the direction of the wind. Probably the prevalent wind, being westerly (S.W. or N.W.), the inhabited parts of Llanslamlet get more of the smoke than the houses on the western slope in Clase and St. John. Nevertheless, so far as Mr. E. Davies' figures go, they appear to indicate that the death-rates of the places thus most exposed contrast favourably with the death-rate of Swansea proper, which is least exposed to the smoke, both as respects the general mortality from all causes and the mortality from zymotic diseases, the infant mortality (under one year) being not very different in all three districts. When, however, we come to look at the proportion of the deaths which was caused by pulmonary diseases, we find that whereas those from phthisis formed nearly the same proportion of the whole of the deaths in all three districts, the proportion of deaths from the more acute forms of disease—croup, bronchitis, pneumonia, and pleurisy at all ages—was distinctly highest in Llansamlet, which I have said is most exposed to the smoke, and as respects croup and the respiratory diseases of infancy, notably higher in Clase and St. John than in the town of Swansea. Considering the irritating nature of the smoke upon the pulmonary organs, it is possible there may be some etiological connexion between these two facts, although of course the connexion may be open to some other explanation, as, for instance, the more elevated and exposed situation of these hill-side dwellings. However this may be, I am assured that the smoke is a source of especial distress to persons sick with pulmonary ailments.

Sources of nuisance.

With respect to the sources from which the obnoxious emanations take place in copper smelting, I have pointed out above that, in every stage of the process, some of these emanations are given off, but by far the largest amount, and especially the largest amount of arsenious acid, is given off in the calcining operations, the actual quantity varying with the chemical constitution of the particular ores under treatment.

Methods of lessening the nuisance.

It is to calcining operations, then, that the principal attention has been directed by those manufacturers who have endeavoured to lessen the nuisance created by works of this character. Mr. H. Hussey Vivian was, I believe, the first to take this matter seriously in hand. Others have followed his lead more or less completely, and with more or less satisfactory results. It will now be my business to tell what has been done.

These lines have been followed by Mr. Vivian and others: Attempts have been made to wash the fume, and thus deprive it of its noxious elements before allowing it to escape; to collect and utilise some of the sulphurous acid fume by converting it into sulphuric acid; to lessen the amount of fume escaping by cooling it, and favouring deposition of solid matters, in long flues, and lastly, to discharge the fume at such an elevation as shall ensure its being largely diluted with atmospheric air before it falls to the earth. The two last proceedings have usually been conjoined.

1°. Washing the fume.

1°. *Washing the Fume.*—We learn from the evidence given by Mr. H. Hussey Vivian before the Noxious Vapours Commission, that so long

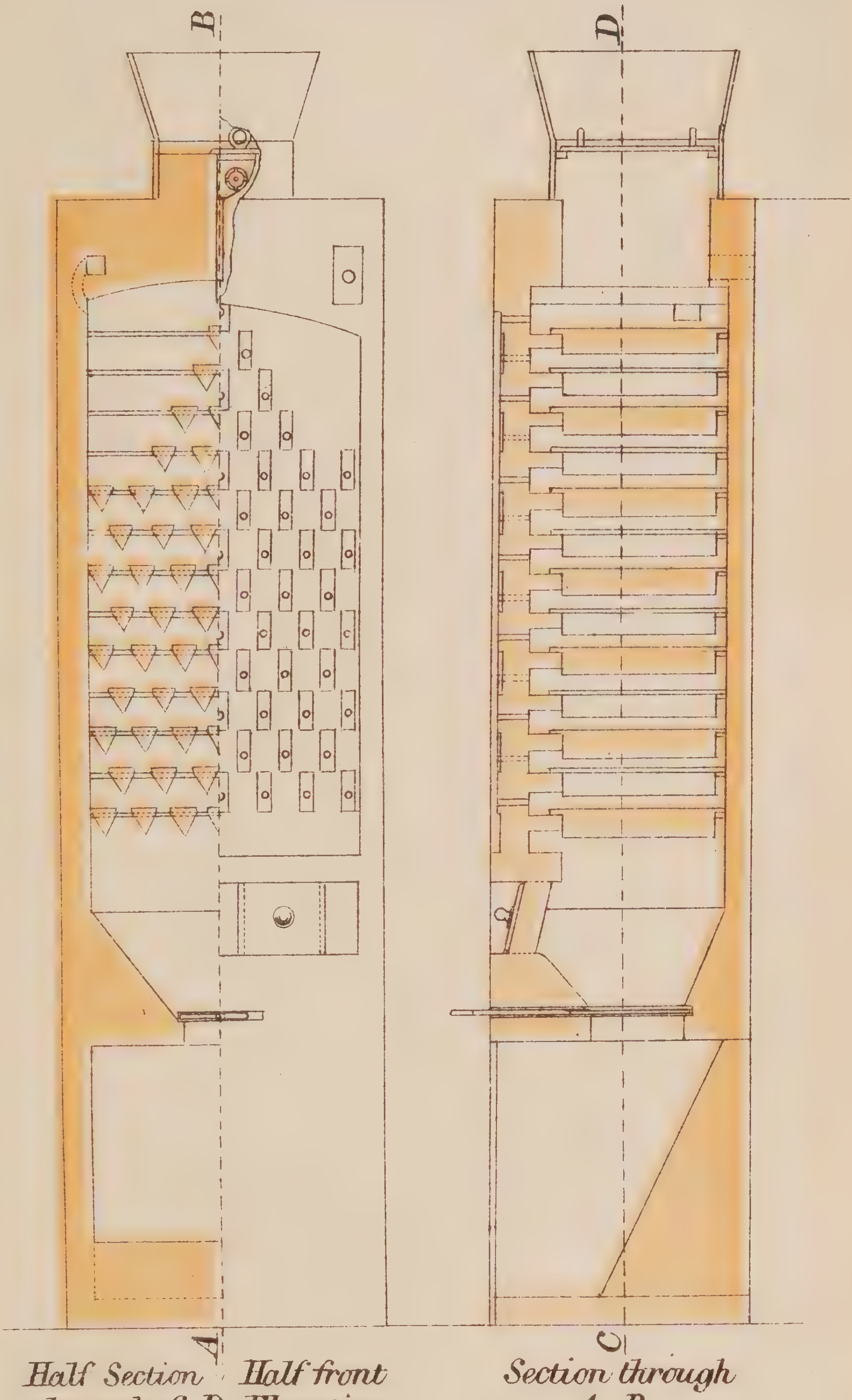
ago as 1821 his father adopted this method of dealing with the smoke from the calciners at the Hafod Works, using a shower chamber, in conjunction however with long flues and high chimney stacks; the result being that the arsenic and fluorides and the sulphuric acid were arrested, but that the greater part of the sulphurous acid escaped condensation. At that time large quantities of fluor spar went into the calciners, and I have no question that the water shower did good service in decomposing the irritating fluoride of silicon which must otherwise have been given off from the stacks. A town committee, assisted professionally by Mr. Phillips and Dr. Faraday, reported most favourably of the results of Mr. Vivian's proceeding. When Mr. H. Hussey Vivian took charge of the works in 1845, he says that he found that the shower chamber had long been abandoned, and it has not since been restored. As I understand the case, the reason of this is that arsenious acid and copper, whether as dust or sulphate, are found to be more easily and conveniently arrested in another way. The absence of fluoride of silicon from the smoke under all but exceptional circumstances has removed all necessity for the use of water on account of that gas, while even the shower chamber failed to arrest the sulphurous acid gas. A similar attempt to wash the fume was made at Mr. Neville's works at Llanelly. Dr. Thomas Williams gives an account of the arrangements there. All the smoke from the calcining furnaces was conducted through chambers, filled lightly with "clinkers," upon which a shower of water fell from the roof of the chamber. The water which ran away was very acid, contained considerable quantities of sulphuric and arsenious acids, a small amount of sulphurous acid, and, in addition, copper, iron, and lime. Dr. Thomas Williams says that neither arsenic nor copper could be detected in the deposits in the flues subsequently to the smoke passing through the washer. At these works, too, the washer has been given up.

2°. Collection of the sulphurous acid.

2°. *Collection of Sulphurous Acid and conversion of it into Sulphuric Acid.*—This has been done at four of the works I have visited, namely, the Hafod Works and the Port Tennant Works at Swansea, and at the works of Newton, Keates, & Co., and of the St. Helens Copper Company at St. Helens; but a different kind of apparatus has been used at each. At the present time this proceeding is not being continued at Port Tennant. It has only been applied, and could only be applied, so far as is apparent at present, to arresting the sulphurous acid given off in the calcining process; since, in order to make sulphuric acid, the sulphurous acid gas must not be too much diluted with air, and that which is given off from the melting and roasting furnaces is very largely indeed thus diluted. At the Hafod Works, when Mr. Vivian has to calcine an ore or a regulus sufficiently rich in sulphur to burn by itself, he calcines it in the "Gerstenhöffer kiln," having first reduced the ore to fine powder, an essential proceeding prior to the use of this kiln. Through Mr. Vivian's courtesy I am enabled to give a drawing (Plate XXVIII.) in which the essential points of construction of this apparatus are represented, and which will assist me in describing it. It consists of a long vertical chamber of the shape and dimensions represented in the drawing (except that in reality it is longer than represented), fitted with rows of fire-brick bars in the form of equilateral triangles, the points being downwards, and one flat surface presented to the ore in falling. In the drawing only 13 rows of bars are shown, but in the kiln in use at Hafod there are 20 such rows, and there are several of such kilns arranged side by side in a set. The powder to be calcined is introduced into a hopper on the top of the kiln, and fed in continuously through a slit, corresponding in position and

Cerstenhöffer Kiln

Scale $\frac{1}{8}$ inch to a foot.



Half Section through C. D *Half front Elevation.* *Section through A. B.*

Dangerfield Lith. 22 Bedford St Covent Garden

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Mr. Vivian says the kiln is well adapted to calcine such richly sulphurous ores as the Tharsis, reducing 46 or 48 per cent. of sulphur present to 4 per cent.; but these ores are usually burned in broken pieces, and the use of the Gerstenhöffer kiln necessitates a preliminary reduction to powder. It is not adapted for any of the processes of copper smelting in advance of the calcination of the regulus. As to the saving of sulphur effected in the smelting when the calcinations are effected in this manner, Mr. Vivian made a statement to the Noxious Vapours Commission, pointing out the proportion of the sulphur theoretically going to the sulphuric acid chambers and to the chimneys respectively, in the smelting of an average ore containing 28 per cent. of sulphur, or 28 tons of sulphur in 100 tons of ore. In order, I hope, to present this statement in a form that will be easily comprehended, I have thrown it into the form of a scheme, representing each stage of the smelting as carried on at the Hafod Works (scheme No. 1, p. 260).

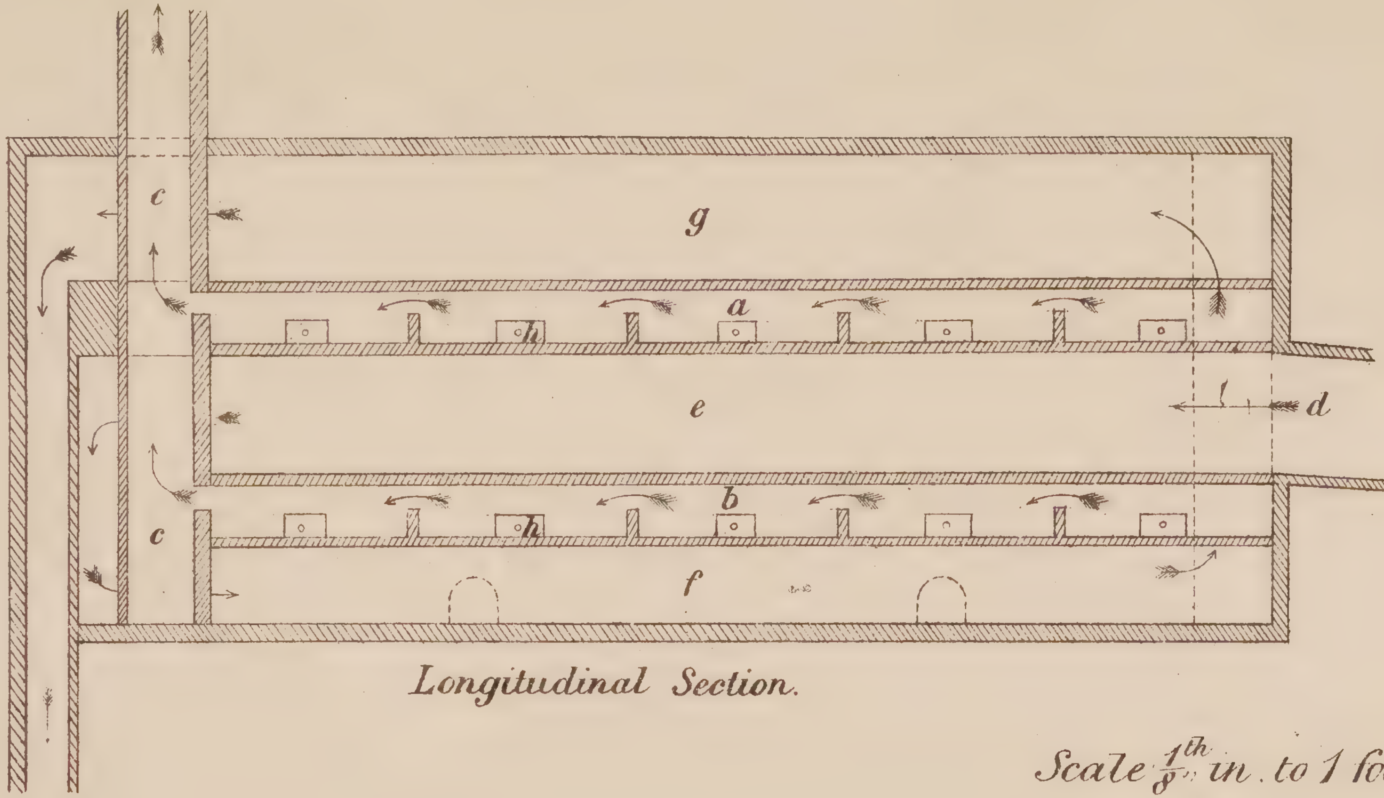
The general result is that theoretically a saving of 77·2 per cent. of all the sulphur is effected. Practically, however, Mr. Vivian says the saving at his works has fallen much short of this, and has only amounted to 40 per cent.; the difference between the theoretical and practical results being due to various accidental causes inevitable to working on a large scale, such as occasional loss from down draughts, loss during the drawing of charges, loss in consequence of escape from the vitriol chambers, &c. But Mr. Vivian showed that under this arrangement the sulphuric acid that does escape condensation is of comparatively little strength, being largely diluted with atmospheric air.

I must not fail to point out here that the mere utilisation of the sulphurous fume for the making of sulphuric acid, may result in the substitution of one nuisance for another. (*See* Sulphuric Acid-making).

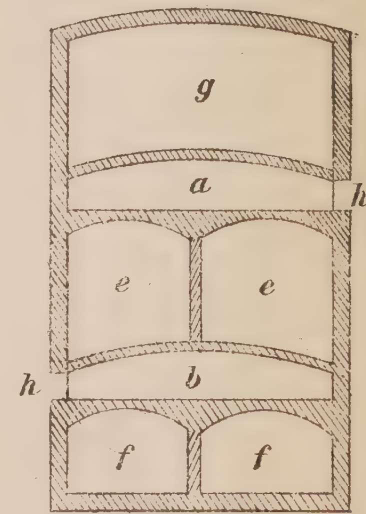
At the Port Tennant Works at Swansea it has been and still is the practice to calcine the ore-furnace metal after grinding it (but not so finely as it requires to be ground for burning in a Gerstenhöffer kiln) in a muffle calciner. The principal muffle calciner is constructed upon a plan very similar to one in use at the works of the same firm in Chili, the heat for calcination being the waste heat proceeding from one of their ore-metal furnaces. Plate XXIX. represents, in two sections, the leading points of construction of this furnace: *a* and *b* are two muffles, constructed of fire-bricks, each of which is 1 foot 8 inches high and divided into five compartments by partitions, between which in the middle of the length of each partition near the roof is a communication with the adjoining compartment. At one end, both muffles communicate with an ascending flue, *c*, to carry away the gas. The waste heat from the furnace enters at *d*, and first passes through a double flue, *e*, to the further end, from which it is conducted by another pair of flues, *f*, beneath the lower muffle; it then ascends by flues to a flue, *g*, which passes above the top of the upper muffle, and from this it escapes to the chimney; *h* are doors, each having a small opening for admission of air. The doors for the upper muffle are on the opposite side of the calciner to those of the lower muffle. The material to be calcined is spread upon the floor of each compartment, and is "rabbled" or turned over by an iron tool as often as may be requisite to ensure its being equably burned. The arrows indicate the course of the gas from the muffles and of the hot air from the furnace respectively. The gas flue, up to the end of last year, was so arranged as that the sulphurous acid generated could either be conducted to the vitriol chamber or be discharged from the chimney of the works, since up to that time it was in part converted into sulphuric acid; but since the end of last year the connexion with the sulphuric acid apparatus has been broken off, and all he gas goes away by the chimney.

To face Page 268.

MUFFLE CALCINER IN USE AT PORT TENNANT WORKS.



Longitudinal Section.



Transverse Section.

Scale $\frac{1}{8}^{th}$ in. to 1 foot.

DANGERFIELD. LITH. 22. BEDFORD ST COVENT GARDEN.

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flues to the chimneys. But in what I may call the roasting-house, where all the roasters in use are ranged on one side and a number of ore-furnaces on the other side, the flues rising from all these furnaces enter a capacious brick flue running through the length of the house on each side a few feet above the furnaces. Each of these flues terminates in a separate chamber, 20 feet long by 20 feet high, and 6 feet wide, which is partly underground and which is provided with a baulk or partition of brick rising up several feet from the bottom, against which the current of gas, &c. is made to beat, and by which deposition is favoured. The flues from these two chambers unite then in a flue 6 feet wide and 8 feet high, and this leads to a very long wide chamber, divided by partitions so as to constitute a zig-zag. From this a flue conducts to another deposit chamber close to the foot of the taller stack. Deposit occurs in all these chambers and flues. Mr. Evans, the manager, told me that, in his opinion, the chief loss of copper occurred in the roasting, and it was for this reason that he connected these capacious flues and chambers with the roasters. The deposit in these large flues contains on analysis 23·44 per cent. of copper, of which 19·59 are soluble in water, and 5·60 per cent. of arsenic. The tall chimney stacks are, under ordinary circumstances, sufficiently high to obviate any nuisance to the town of Llanelly from the sulphurous acid escaping from them; but I am informed on satisfactory authority that in some conditions of the weather the smoke falls into the town, when it is disagreeably perceptible, sometimes even close to the works. But, for all that, the remedy appears to be as successful as is practically attainable at present under the existing mode of copper smelting.

THE WET PROCESS OF EXTRACTION OF COPPER FROM ITS ORES.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
May 15, 1877	Widnes Metal Company.	Widnes.	—
Jan. 24, 1879	Tharsis Sulphur and Copper Company.	Oldbury.	
May 16, „	Eyton Copper Company.	Mostyn.	—
July 1, „	Gibbs - -	Jarrow.	—
„ „ „	Bede Metal and Chemical Company.	Ditto - -	Dry copper smelting.
„ „ „	Tharsis Sulphur and Copper Company.	Hebburn - -	Ditto. Purification of condensed acid.
„ 18, „	South Devon Metal and Chemical Company.	South Down, Devonport.	—
Nov. 26, „	Tharsis Sulphur and Copper Company.	Glasgow - -	Dry copper smelting. Purification of condensed acid.

Process

Burnt pyrites, that is to say, pyrites containing a small proportion of copper, after having been used as a source of sulphur in the manufacture of sulphuric acid, are treated by what is termed "the wet process" for

the extraction of the copper they contain in the form partly of sulphide and partly of oxide. The burnt ore, after having been duly crushed, is well mixed with a proportion of common salt and introduced into an open or close (muffle) calciner, where it is calcined either by means of a fire or, as at the South Down Works, by means of Siemens' gas arrangement. From time to time it is rabbled through the doors at the sides of the calciner. The object of the calcination is to oxidise the copper, which is first converted into sulphate of copper, and then into chloride of copper by reaction of the chloride of sodium upon that compound, sulphate of soda being formed at the same time. Hydrochloric acid and sulphurous acid are given off, the latter in larger quantity the larger the quantity of sulphur left in the pyrites after burning. The calcined mixture always contains, in addition, a little oxide of copper. When the calcination is completed, the material is raked out, usually on to the floor of the works, and is then transferred to a wooden tank, where it is lixiviated first with hot water and subsequently with weak hydrochloric acid. The ordinary practice is to use in the lixiviation, instead of water or in place of some of the washings with water, some of the weak solutions from previous washings, so as to concentrate them. If silver be present it may be precipitated by means of iodide of potassium. The solution of copper is next introduced into a tank into which scrap iron is thrown ; the copper is thus precipitated and the solution comes to contain, in place of a salt of copper, a salt of iron.

Description of Process at the Tharsis Works.

Dr. L. Mayer, of the Tharsis Company's Works in Glasgow, has obligingly furnished me with the following description of the processes carried on at those works and at Hebburn. I cannot do better than give this description in his own words. The process of purification of the "tower liquor" is, I understand, claimed as his own invention. He says :—

"'Burnt Ores,' as they are used for the extraction of copper by the 'wet process,' contain, besides the copper, a number of other metals, such as arsenic, antimony, tin, bismuth, lead, iron, &c., and also sulphur. Amongst these the first two named are very frequently found in refined copper in comparatively larger quantities, and in every such case the quality of the copper is seriously impaired. Such impurities have, therefore, to be removed from the copper, and hitherto this has chiefly been done *after* they had entered into combination, and formed an alloy with the same. The processes to be described effect a separation of the copper and those impurities *before* they can combine. To make this clear I will shortly explain the principal points of the 'wet method' of extracting copper.

Calcination.

"The '*burnt ores,*' as they are received from the vitriol makers, consist, in the case of Spanish and Portuguese pyrites, principally of oxide of iron with a percentage of copper varying from two to five. The larger part of this copper is insoluble in water and dilute hydrochloric and sulphuric acid ; and the first step of the wet process has for its aim to make the whole of the copper soluble in these liquids. This is done by what is technically called 'roasting' or 'calcining' the ores. For that purpose the ores are mixed with a certain quantity of common salt and ground. They are then transferred to furnaces, 'calciners,' and subjected to a red heat whilst frequently stirred, so as to give the air access to every particle of the mixture. When it is found that nearly the whole of the copper can be dissolved out of the ores by means of water and dilute acids, it is taken out of the furnace and allowed to cool. After having gone through this calcining process the ore is now called '*calcined ore.*' The principal chemical changes

which take place during this operation are, the oxidation of the sulphur and formation of sulphuric acid, which in turn acts upon the common salt, and brings about the formation of sulphate of soda, chlorides of heavy metals, chlorine, hydrochloric acid, and other products. The chlorine, hydrochloric acid, &c., again act upon the various metallic compounds, and form chlorides which are more or less volatile. At the end of the operation the greater part of the copper is soluble in water as chloride, and the remainder soluble in dilute acids. A great part however of the chlorine, hydrochloric acid, oxidised sulphur, &c., which are generated during this process escapes, and along with it volatile compounds of copper, arsenic, antimony, lead, bismuth, and other metals. It is therefore necessary to condense these products, and this is done by leading the gases and vapours through long flues, and afterwards through a 'coke tower.' In these flues the less volatile portion of the metallic compounds accumulates, whilst the more volatile arsenic and antimony, together with some of the copper and other metals as well as the hydrochloric acid, sulphuric anhydride, sulphurous acid or chlorine, as the case may be, condense and dissolve in the water which flows down the 'coke tower.' The product of this condensation runs through an opening in the bottom of the 'coke tower' and is generally called 'tower liquor.' It is a weak contaminated solution of hydrochloric, sulphuric, and sometimes sulphurous acid (the latter is now and then replaced by chlorine), and serves to extract from the 'calcined ore' that part of the copper which is not soluble in water.

Condensation of vapours.

Lixiviation.

" In the 'washing' or '*lixiviating*' process, the above-named 'calcined ores' are treated, in suitably constructed tanks, either first with water alone or afterwards with 'tower liquor,' or at once with a mixture of both, until the copper is washed out. The residual ore is called 'iron ore' or 'purple ore.' It consists of oxides of iron, and contains rather less than 0·1 per cent. of copper. It is used as a material for fettling the furnaces in iron works, and, since a few years, also for the production of pig iron. It will be seen that those solutions or '*copper liquors*' which have been prepared with 'tower liquor,' are contaminated with all the arsenic and antimony (etc.) which the latter contained. When the 'copper liquor' is considered to be sufficiently concentrated, the silver and gold, amounting to about 0·002 to 0·003 per cent. is recovered therefrom by a special process, after which it is transferred to other sets of tanks, and the copper recovered in the metallic state by the '*precipitation*' process. For this purpose metallic iron is thrown into the tanks amongst the 'copper liquor.' The iron dissolves gradually, and metallic copper takes its place in the form of a heavy crystalline precipitate. Along with this precipitation of metallic copper, precipitation of other metals present in the liquor takes place. The bulk of the arsenic and antimony which was contained in the 'tower liquor' precipitates as metal upon the metallic copper, whilst besides, a compound of the oxides of arsenic and iron is mechanically mixed with precipitated copper. After the whole of the copper has disappeared from the liquor, the remaining 'iron solution' is run to waste. It contains chloride and sulphate of sodium and ferrous chloride, and is the first waste product of the process. The same process is repeated until the accumulation of 'copper precipitate' is deemed sufficient, after which the whole contents of the tank are taken out, washed with water, and freed from small pieces of metallic iron, etc., and the clean precipitate delivered to the refinery, where it is smelted down. The principal object of the first smelting is to get rid of all that which is not copper, and the product is called 'polister,' or 'set copper.' In the case of arsenic and antimony, however, the bulk enters into combination with the copper. It is there-

Precipitation.

Smelting.

fore clear that the 'blister' or 'set copper' will contain all the more of those metals, the more the precipitate was contaminated with them—the more the 'tower liquor' used for the lixiviation of the ores was contaminated. Such a 'blister' or 'set-copper' cannot at once be refined and brought into the condition of marketable copper, but must once or twice be subjected to the process of roasting and re-smelting in order to drive off the impurities. This roasting and re-smelting is a very costly operation; 1. On account of the coals and labour which it requires; and 2., because about one third of the copper is oxidised during each operation and driven into the slag, and has to be recovered therefrom by a costly process. Besides this, such copper will not be of first quality, nor command the highest price in the market. All these difficulties do not exist, and the 'blister copper' can be made into best marketable copper by a single refining operation, when a pure acid is employed. The refinery produces the second waste product 'clean slags.'

"To procure a pure acid is the object of the first process to be described:—

Purification of "tower liquor."

"The purification of the 'tower liquor.' It is effected by converting those metals, the sulphides of which are insoluble in acids, into sulphides. This is done in Glasgow by means of a solution containing principally polysulphides of calcium, which forms itself naturally at Messrs. Tennant and Co.'s Alkali Works, St. Rollox (tank waste liquor). The solution of the sulphides is run through a leaden pipe to the bottom of a tank previously filled with 'tower liquor,' agitation of the liquid being kept up during the whole time. The insoluble sulphides formed during this operation, together with the purified acid, are now at once run by gravitation into a second tank of considerably greater capacity, and allowed to settle. After about 15 minutes the settling is complete, and the clear liquor on the top of the precipitate is run into a third tank which stands on a correspondingly lower level than the second. This third tank is divided into two very unequal compartments by means of a perforated board which is covered, at the side of the larger compartment into which the liquor runs first, with a layer of matting and then with flannel. By these means the smallest particles of precipitate which may float in the liquor are retained by the flannel filter, and a pure perfectly clear acid flows into the smaller compartment of this filter tank. These three sets of tanks above referred to are covered airtight, and the pipes which carry the liquors from one tank to another are also fitted airtight to these tanks. They are, besides, connected with a flue leading to the coke tower, where the sulphhydric acid which escapes is decomposed, and the products condensed. This arrangement causes any leakage to draw air from the outer atmosphere into the tanks; and with the most ordinary care these operations can be carried on without the slightest annoyance from smell. The purified acid which has filtered into the smaller compartment of the third tank smells strongly of sulphhydric acid, and must be freed therefrom before it can be used. For this purpose, a small stream of 'copper liquor' is introduced into the pipe through which the purified acid leaves the third tank; and when it flows into a fourth tank it is perfectly inodorous, but of brownish appearance, owing to the sulphide of copper formed in deodorising the acid. To get rid of this precipitate, the fourth tank is furnished with a false bottom, on the top of which heather, straw, and some 'iron ore' are placed so as to form a filter. After the acid has passed this filter, it has a bluish tint from an excess of 'copper liquor' used for destroying the smell, but it is perfectly clear, and free from arsenic, antimony, bismuth, &c., &c. The acid so purified is now used for lixiviating the ores.

"It now remains to deal with the precipitated sulphides which were

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left in the second tank, and which consist principally of sulphide of copper, besides the sulphides of lead, arsenic (4–5 per cent.), antimony, &c. and uncombined sulphur. Amongst the different methods which may be applied, the following is the most preferable. It is based upon the fact that if sulphides of arsenic and antimony are boiled with 'copper liquor,' or with solutions of other metals such as lead in hydrochloric acid, &c., arsenic and antimony go into solution as oxides, whilst the other metal (copper) takes their place in the precipitate as sulphide. The practical working is as follows: when a sufficient quantity of sulphides has accumulated in the second tank, the muddy mixture is deodorised by the introduction of some 'copper liquor,' and then transferred (pumped) to special tanks, the remaining empty two-thirds of which are filled with 'copper liquor.' The whole contents are now heated up with steam and kept near the boiling point until the last trace of copper has been precipitated. This operation is repeated until the copper does no more disappear from the liquor after prolonged boiling. The liquors which have been deprived of their copper in this manner are separated from the precipitate by settling, and may be run to waste, or the arsenic and antimony are recovered therefrom in the manner hereafter described. When the sulphides are thus purified they have to be dried. For this purpose they are thrown upon a filter about 40 feet in length and about 8 feet broad. This filter consists of a false bottom constructed of perforated tiles which rest in a cavity of the ground upon some support, so as to leave room for the liquid which filters through to accumulate, and flow away into a tank which is sunk into the ground. The tiles are covered with heather, straw, and 'iron ore' so as to form a perfect filter, and the sides of the cavity,—which lie at an angle to each other and so form a gutter,—and the bottom of it are lined with puddle clay. After the liquid has been thus filtered, the sulphides are removed and still further dried by storing them at a place where spent heat may be made available. The dried sulphides may be either smelted down by themselves, or may be used as a reducing agent in the recovery of copper from slag. The liquor which has drained through the filter and has accumulated in the tank which is sunk into the ground contains a little copper, which may be recovered either by precipitating it by means of sulphides or by metallic iron.

"The antimony and arsenic are recovered from the solution referred to, by means of sulphhydric acid. Sulphide of antimony is thrown down first, free from arsenic. This precipitate is separated, and again gas passed through the liquid until a yellow precipitate appears and remains. The quantity of this second precipitate is very small. It is a mixture of both metals, and is disposed of by suspending it in a new quantity of the original solution, whereby the sulphide of arsenic is replaced by sulphide of antimony. From the liquid which has thus been freed from antimony the arsenic is recovered as a yellow precipitate by further treatment with sulphhydric acid, and is, when dried, a marketable product; whilst the antimony may be recovered from the first precipitate by well-known processes.

"When this 'sulphide process' was introduced at the company's works at Hebburn-on-Tyne in the year 1875, it became necessary to prepare a solution of polysulphides from alkali waste artificially. This has been accomplished in the following manner:—Tanks were sunk into the ground, made of puddle clay and thin boards of wood, and capable of receiving about 45 tons of alkali waste. The dimensions are about 10 feet broad, 35 feet long, and 4 feet deep. Each tank is furnished with a false bottom (made of perforated tiles) in such a manner that a space of about 4 inches is left between it and the real bottom of

the tank. Those two sides of the tank which are furthest apart from each other are not approached nearer by the false bottom than about 1 foot, and a partition made of wood, runs parallel with, and about 1 foot distant from each of these smaller sides of the tank, from the top down to the lower edge of the false bottom. By means of this arrangement the atmosphere can freely penetrate the alkali waste from the bottom to its upper surface. After the false bottom has been covered with heather and straw, the tank is filled with alkali waste, and after a few days the whole of its contents is covered with water and allowed to remain there for about 16 hours. It is then found to be a strong solution of polysulphides, hyposulphites and sulphites. This liquor is used for the precipitation of 'tower liquor.' As soon as the tank thus lixiviated has been drained of its liquid contents, the oxidation of the waste recommences and the same process is repeated four or five times, after which the residue is shipped to sea.

"The progress of oxidation has to be watched closely, and rough and ready means of testing in the laboratory had therefore to be provided. The tests employed are the following:—Samples of the oxidising waste are taken from day to day at different distances from the surface. For this purpose the edge of an old boiler tube of about 4 inches diameter, and convenient length, is sharpened so that it easily penetrates into the alkali waste if a rotating motion is imparted to it by means of a handle suitably fixed to the opposite end of the tube. To whatever depth this tube is driven into the heap, it will, on being withdrawn, leave a cylindrical hole, and the matter corresponding to the particular depth can be taken from the inside of the tube. A fixed quantity of a sample so taken is digested for a fixed time with a fixed volume of water, and filtered. The sulphides are estimated with ammoniacal copper solution in one portion of the filtrate, and in another quantity the total amount of the sulphides, hyposulphites, and sulphites is determined by the reducing action which they exert upon ferric oxide in acid solution, sulphocyanide being used as an indicator. This double test is necessary. It is our aim to produce polysulphides and as little of the two other substances as possible, because they destroy a corresponding quantity of sulphhydric acid during the process of mixing with 'tower liquor.' From a comparison of the results obtained by both methods a practical rule has been laid down when the oxidation ought to be interrupted with the best advantage. With the control which these two tests afford it is not difficult to produce a liquor which practically deposits the whole of its sulphur by the simple addition of an acid.

"Another process for the elimination of arsenic from 'copper liquor' was first tried in 1875 and 1876. It is based upon the observations that oxide, or insoluble basic salts of iron, when produced within 'copper liquor,' take up and render insoluble almost every trace of arsenic present in the liquor; and that such precipitates are produced when a ferrous salt, mixed with copper liquor, is heated to about 75° C., cupreous chloride being formed at the same time, which, however, remains dissolved. Such precipitates have come under my notice which contained about 22 per cent. of metallic arsenic. If the ferrous is partly converted into a ferric salt before being mixed with the copper liquor, the re-action takes place with somewhat greater facility.

"In practice, about 2 per cent. of 'iron solution' are mixed with the 'copper liquor' during the process of lixiviating, and the latter operation conducted at an elevated temperature by pumping the liquors from one tank into another by means of 'blow jacks' or 'steam pumps,' instead of by ordinary pumps. The precipitate is retained by the 'iron ore' when the 'copper liquor' is run off.

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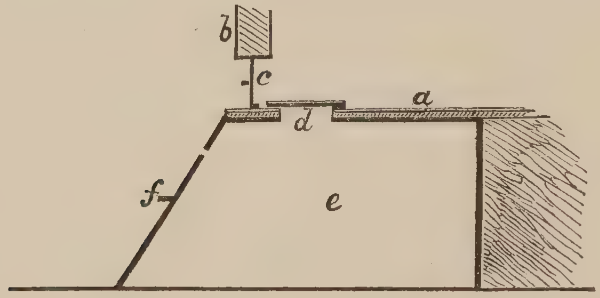
Nuisances and their prevention.

"The best quality of copper, commanding the highest price in the market, is obtained when this process is coupled with that for purifying the 'tower liquor.'"

The wet copper reduction process may give rise to a good deal of nuisance due to the abundant escape of acid fumes from the works. I have been disagreeably impressed by these fumes at a distance of at least half a mile to leeward of wet-copper works. It is customary now, and indeed required by the "Alkali Act, 1874," to condense the fumes which pass from the calciner in the same way that acid fumes from alkali making are condensed, namely, by the use of a wash-tower; so that little or no nuisance arises from that source. But abundant fumes are apt to be given off when the charge is drawn from the calciner; and acid steam rises from the tanks in which the charge is lixiviated: the latter is a nuisance when the lixiviation is performed in tanks open to the air. The purification of the tower liquor, as described by Dr. Mayer, may also be productive of nuisance due to the escape of sulphuretted hydrogen into the atmosphere. Dr. Mayer states in his description of the process how this nuisance may be avoided; but, as a matter of fact, I learn from Dr. Russell, the Medical Officer of Health for Glasgow, that he has received many serious complaints of the nuisance. A similar odour of sulphuretted hydrogen pervades the part of the works at Hebburn, where this purification process is carried on, but I have heard of no nuisance complained of outside the works. Dr. Mayer himself mentioned to me the fact that sometimes there was an escape of sulphuretted hydrogen, and he attributed it, with some degree of probability, to the carelessness of the workmen, who ran in the sulphide solution more rapidly than they ought to do.

To remedy the nuisance arising from drawing the charge at the Tharsis Works, at Oldbury and Hebburn, an iron box is provided beneath the opening at which the charge is drawn. It lies partly under the floor of the calciner as shown on the rough diagram, Fig. 42, in which

Fig. 42.



a represents the floor of the calciner, *b* the front wall, *c* an opening for rabbling closed by its closing plate, *d* an opening which is covered during the progress of the calcination by a removable covering plate and through which the calcined charge is raked into the box *e* which is provided with a pair of doors *f* in front. In this box the charge remains until it is cool enough to be removed without creating a nuisance. The arrangement is an efficient one. Where the lixiviations are performed within a building sufficiently lofty and duly ventilated at the roof, little or no nuisance arises from the acid steam; should it still create a nuisance the tanks might be placed under a hood ventilated into the condenser.

MANUFACTURE OF NICKEL.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Processes or Businesses conjoined.
Jan. 11, 1879 -	Vivian - -	Swansea.	—
„ 23, „ -	H. Wiggin & Co.	Birmingham.	—
„ 25, „ -	Sir J. Mason -	Bromford, Birmingham.	—
May 3, „ -	W. Webb & Co.-	Aston, Birmingham.	—

Ores of nickel.

Nickel ores mostly come to this country for reduction after having undergone a process of "concentration" abroad. They come here either as a "matte" or combination of nickel, cobalt, copper, and iron with sulphur, or as a "speiss," or combination of the nickel and copper with arsenic. It is in the preparation of nickel from the "matte" or "speiss" that nuisance is apt to arise. The smelting of the New Caledonia ore, which is a silicate of nickel and magnesia, being effected without either sulphur or arsenic, is a process that gives rise to no nuisance, and requires therefore no further notice here.

Process of smelting.

The earlier steps in the reduction of the "matte" or "speiss" consist of processes very similar to those employed in the smelting of copper. The objects sought are the further concentration of the material, *i.e.*, the separation of iron from it by alternate calcination and melting by which the iron is slagged off, and then the conversion of the valuable metals present into oxides or soluble salts. The calciners and melting furnaces used are similar in construction to those used in copper smelting, and for the oxidation of the nickel, &c. free access of air is given in the last process. The product of the last operation at the furnaces is then subjected to a series of wet processes. It is first dissolved, by the aid of steam, in water to which hydrochloric acid is added in sufficient quantity, and then the iron present is precipitated from the solution by means of milk of lime, and the solution again filtered. Sulphuretted hydrogen is then passed through the solution to separate the copper and arsenic present, and the solution again filtered. After this the whole process is a wet one in which nothing of an offensive character is or can be given off, and which therefore I need not describe. The foul slags from the melting processes are melted with coke in a cupola furnace, a form of cold-blast furnace. A "matte" separates, which is tapped off from the well at the bottom of the furnace. During melting and the tapping of the slag, arsenical fumes, recognisable by their alliaceous odour, may be freely given off.

Nuisance.

The offensive or noxious matters therefore liable to be given off into the atmosphere from nickel works are similar to those already mentioned as given off from copper works (p. 262), and in addition sulphuretted hydrogen and some alliaceous smelling vapour of metallic arsenic. Indeed, when complaints have arisen in respect of such works, it is of the sulphurous acid, sulphuretted hydrogen, or arsenic that mention has been made. At Swansea these gases are so mixed up with similar emanations from other kinds of works in the valley, that it has not been clearly made out that offensive vapours perceived there have issued actually from the nickel works, although there can be no doubt whatever, and it is readily admitted, that they have contributed. It has been otherwise at Birmingham, where nuisances have been distinctly traced

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Prevention of nuisance.

to such works, and where, under the direction of an able chemist, Dr. Hill, the Medical Officer of Health for the borough, means have been adopted with a view to their abatement.

At Mr. Vivian's works at Swansea the fumes from the calciners and furnaces have been dealt with in a similar manner to those from the copper calciners at the Hafod Copper Works. A chimney shaft, 100 feet high, is in use, and there is a flue about 70 yards in length leading to it underground from the calciner. This flue is 5 feet high and $3\frac{1}{2}$ feet wide, and about 30 yards from the calciner is widened out into a deposit chamber, 35 feet long, 10 feet high, and 16 feet wide, in which chamber, as well as in the flues, most of the arsenious acid is collected. The sulphurous acid goes off by the chimney into the atmosphere; unfortunately this chimney is in a low position in the valley where the works are situated. When, as occasionally appears to have been the case, calcination has been performed in "clamps," without the use of the ordinary calciner, all the fumes produced have passed off into the atmosphere, and at such times it appears, from the evidence of one witness examined by the Noxious Vapours Commission, that the well-known odour of the vapour of metallic arsenic has been recognised in the atmosphere of the neighbourhood. The remedy for this is obvious.

At the works of Messrs. Wiggin & Co. at Birmingham, where the manager tells me but little arseniuretted ore is received, the calciners communicate with a flue 150 feet long, terminating in a chimney shaft 150 feet high. The flue is 4 feet high by 2 feet wide. The melting furnaces communicate with a flue of similar capacity, but terminating in a different chimney, which is 70 feet high. In consequence of complaints made, this firm is now putting up a washing or scrubbing arrangement, with a view to endeavouring to arrest some at least of the sulphurous acid given off. From the vessel in which the copper is precipitated with sulphuretted hydrogen a pipe conducts waste gas into the side of one of their boiler fires, where it is consumed.

LEAD SMELTING.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Jan. 6, 1879 -	White Rock Works.	Swansea.	—
„ 10, „ -	Neville, Druce, & Co.	Llanelly.	—
Feb. 26, „ -	St. Helens Lead Smelting Company.	St. Helens, Lancashire.	—
April 9, „ -	Duke of Devonshire.	Grassington, Yorkshire.	—
May 15, „ -	Walker, Parker, & Co.	Bagillt, Flintshire.	—
„ 16, „ -	Adam Eyton -	Holywell, Ditto.	—
„ 21, „ -	Snailbeach Lead Company.	Near Shrewsbury.	—
„ „ „ -	Pontesbury Lead Works.	Ditto.	—
June 14, „ -	Wass and Sons -	Lea, near Matlock.	—
„ 16, „ -	Ditto - -	Alderwasley, Derbyshire.	—
„ 17, „ -	John Yorke	Pateley Bridge.	—

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
July 1, 1879	Bewick, Partners	Hebburn - on - Tyne.	—
" 2, " -	Cookson and Co.	Howden - on - Tyne.	—
" 3, " -	London Lead Smelting Company.	Stanhope, Durham.	—
" 4, " -	Locke, Blackett, & Co.	Wallsend - on - Tyne.	—
" 7, " -	London Lead Smelting Company.	Nent Head, Alston.	—
" 8, " -	Lead Hills Mining and Smelting Company.	Lead Hills, Dumfrieshire.	—
" " " -	Duke of Buccleuch.	Wanlockhead, Dumfrieshire.	—
" 19, " -	Par Lead Smelting Company.	Par, Cornwall.	—
Oct. 16, " -	Panther Lead Works.	Bristol.	—
" " " -	Blackswarth Lead Works.	Ditto.	—
" " " -	Weston, Sons, & Co.	Ditto.	—

Ores of lead.

The ores of lead which are raised in this country for smelting here, or which are received at smelting works from foreign countries, consist chiefly of galena (sulphide of lead), carbonates, sulphates, and phosphates. Of these the sulphide is by far in the most common use, and hence in describing the process of lead smelting it will be understood that it is to this ore that reference is principally made. The ore arrives at the works more or less "dressed," *i.e.*, deprived by a washing process, carried on at the mines, of the greater part of the gangue or matrix raised with it. The quantity of lead in the dressed ores varies, from a small quantity in some highly argentiferous ores which are smelted more for the sake of the silver than of the lead they contain, to as much as 80 per cent. or more. The other metals beside lead which are found in lead ores, in various proportions, are silver, gold, copper, antimony, arsenic, zinc, and iron.

Methods of smelting.

Several methods of smelting lead ores are in use in this country; the selection of one or other of these methods at any particular work being determined partly by the kind of ore (its chemical composition or physical condition) habitually received for smelting, partly upon the cost of coal or other fuel, partly upon the facility of obtaining particular fluxes, and partly, I think, upon the traditions of the part of the country where the works are established. It will be convenient to describe these methods briefly in the following order:—

1. Flintshire method.

1. *The Flintshire method*, which is in use both in North and South Wales, and in Yorkshire, Shropshire, and Derbyshire. The furnace used is a reverberatory furnace, of the form shown in the plan Fig. 43. There are on one side three openings, capable of being closed by iron doors, and used by the workman for manipulating the charge. On the other side, in the middle, is an opening, closed during working by means of clay patted up against it, and opposite to this opening is an iron pot, into which the lead is tapped off when the operation is completed. On

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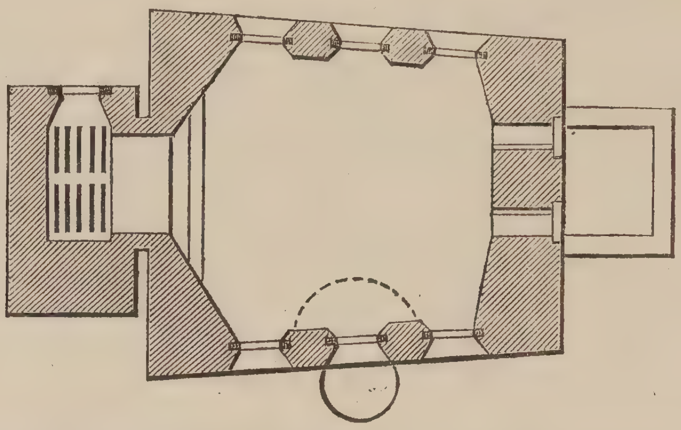
each side of this is a door used for taking out slag. The charge is introduced by a hopper in the roof of the furnace. The bed of the

Fig. 43.



furnace is made of slags, moulded into the proper form when in a plastic state, and it is depressed or sloped in the middle towards the tap hole, so as to form in this way a sort of well in which the lead accumulates as it flows out of the charge. The fire-place is at one end and has an ash-pit which contains water; the flue opening is at the opposite end. The charge of ore, usually 21 cwts., is introduced by the hopper and spread over the floor, care being taken, however, that none of it shall lie on the most depressed part near the tap hole. The process of the smelting may be described as having two stages, the first being calcination of the ore, and the second the melting down and reduction of the metal. During the first stage, which lasts about 1½ hours, the doors are left open or are only partially closed, so as to allow of access of a sufficiency of air, and the heat is regulated by keeping down the damper considerably. During the whole process of calcination a workman repeatedly rabbles or turns over the charge so as to expose all parts of it to the action of the air and heat. The doors furthest from the furnace are then closed, and the fire is urged so as to bring about the commencement of the second stage of the operation, when reduction begins to take place and lead to trickle down into the well. At the expiration of about two hours the doors are all closed, the damper is fully raised, and the whole charge is melted down into the well, which then contains lead at the bottom and slag at the top. A shovelful of lime is thrown upon this and mixed with the slag, with the object, it is said, of thickening it, and the slag is with any unreduced portions of ore pushed back on to the bed of the furnace and re-melted. When it has all run down more lime is added, and the thickened slag is again pushed back to drain the lead out. The lead is then tapped through a hole made by driving an iron bar into the well through the clay stopping. The slag, known as "grey slag," is then raked out. The time occupied in working off a charge is about five hours. Ignited coal with slack is thrown upon the surface of the lead in the pot, and subsequently skimmed off with the scoriæ and thrown back into the furnace for more lead to sweat out.

2. Cornish method.

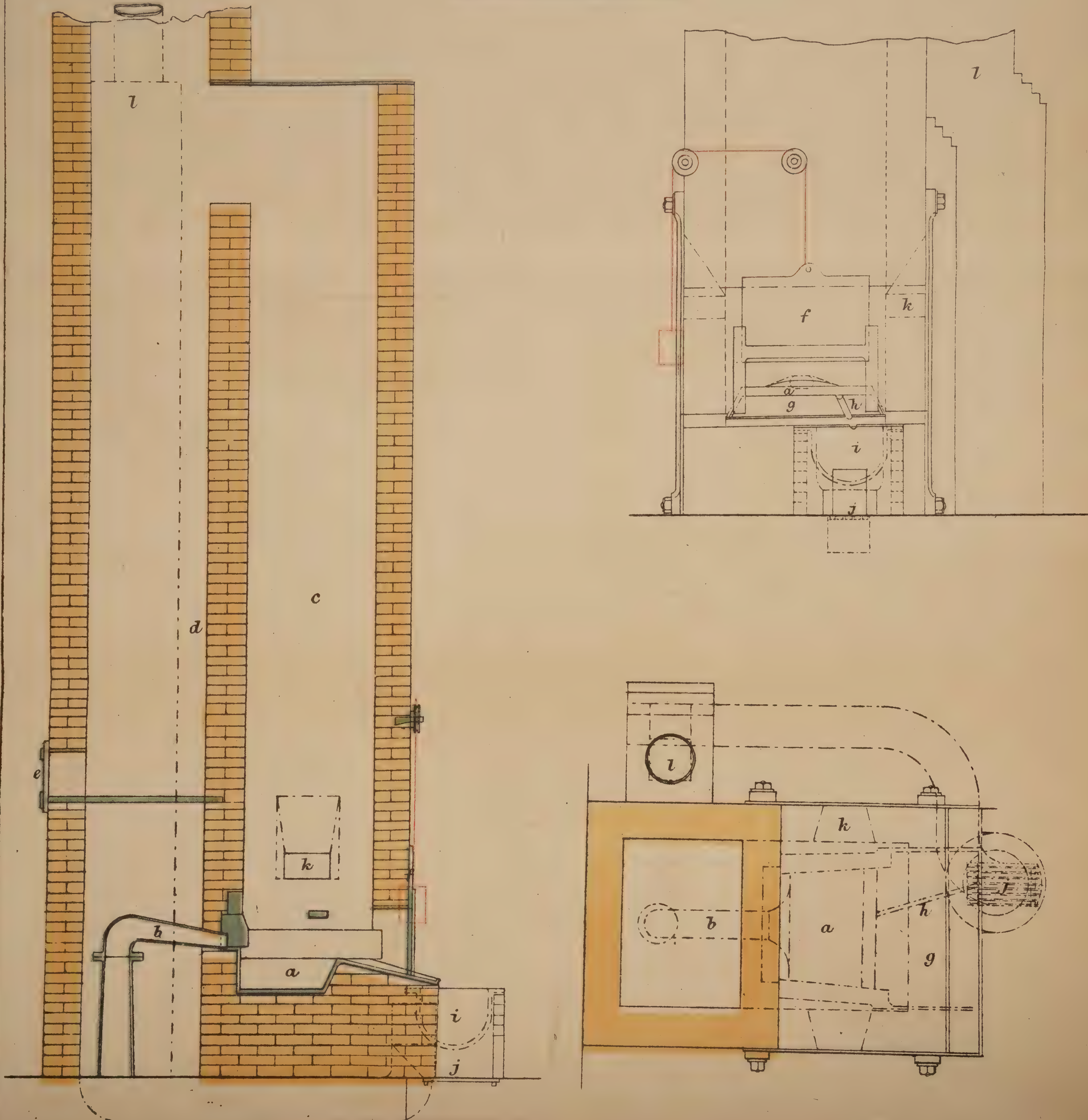
2. *The Cornish method* in use at Par, where it is traditional, requires two reverberatory furnaces. The first, with a flat floor, is used for calcining the ore, which, after calcination with the addition of a little lime to prevent clotting in the early stage, is drawn out and introduced into what is termed a "flowing furnace." This is a reverberatory furnace, similar to that used in the Flintshire process, but the charge, mixed with culm (small anthracite) is introduced not by a hopper in the roof, but through the doors opposite the tap hole. The charge is at

ORE HEARTH

AS USED BY

MESSRS COOKSON & CO, HOWDON.

Scale $\frac{3}{8}$ Inch to one Foot



DANGERFIELD, LITH. 22 BEDFORD ST COVENT GARDEN.

once melted down with closed doors and strong heat. At a certain stage of the smelting, scrap iron is introduced into the well of the furnace. The products, which are all run at one time from the tap hole, are first lead, then a regulus or matt, consisting chiefly of protosulphide of iron, but containing other metals such as copper or silver present in the ore, and lastly a slag which, since it is clean, *i.e.*, contains only from 1 to $1\frac{1}{2}$ per cent. of lead, is thrown away.

At some works the first part of the smelting, in which the greater part of the lead is got out, is performed by the Flintshire process, and the grey slag drawn out is then treated by the Cornish process.

3. Smelting by the ore hearth.

3. *Smelting by the "ore hearth"* or "Scotch hearth" is the only method in use, so far as I have been able to observe, in Scotland, Northumberland, Durham, and Cumberland. Plate XXX. represents a form of ore hearth used near Newcastle, the drawing from which it is taken having been furnished to me by Mr. Norman Cookson. It consists of an oblong cast-iron tank or well *a*, about 2 feet 6 inches wide, 2 feet from front to back, and 1 foot deep (at Cookson & Co.'s 6 inches deep), capable of containing about 2 tons of lead (at Cookson & Co.'s about 12 cwts. of lead), with which it is filled to the brim, the surface of the lead forming, in fact, the floor of the hearth. The floor thus formed is enclosed at the sides with blocks of cast iron, and another block of cast iron is placed behind and is perforated for the passage of the twyer *b* that conducts the blast into the furnace about 2 inches above the surface of the lead in the well. A shaft of brickwork *c* proceeds upwards from the hearth to the flue, and there is behind it a blind flue or pit *d*, into which the "hearth ends," or dusty matter which comes off with the fume, may fall, and from which it is removed as requisite by the door *e*. The front opening to the hearth is sometimes provided with a sliding shutter *f*, which by means of a counterpoise can be raised or let down in its groove so as nearly to close in the front of the hearth. Extending forwards from the front of the hearth, and inclining downwards at an angle from it, is a plate of iron *g* called the "forestone," in which there is a groove *h* which leads towards an iron pot *i* kept hot by a little fire *j* beneath. The ore is fed in either from the front or through a hopper *k* at the side. The chimney of the fire which keeps the lead pot hot is shown at *l*. The fuel used is either peat or coal, the latter, however, being the only fuel I have seen employed. A fire of coal being made upon the hearth, and heaped up chiefly behind, a moderate blast is put on and the ore (sometimes previously calcined) is thrown on, and if there be a shutter this is put down. After the lapse of a few minutes the workman introduces a poker and stirs up the fuel and ore, and from time to time repeats the above process with fresh small quantities of ore, adding fuel as it appears requisite. At intervals of a few minutes he raises the shutter and draws forward a portion of the charge on to the forestone and picks out from it portions of "grey slag" which he pushes aside, and ultimately throws off on to the floor of the workshop at the side of the hearth. As the lead forms it runs into the well, and overflows along the channel of the forestone into the pot set to receive it, from which it is ladled into the moulds. It is a process which requires constant manipulation of the charge, two workmen being continually occupied in adding ore or fuel, poking up the charge, &c., at intervals of a few minutes. Lime is used, as in the Flintshire process, to thicken the slags.

4. Smelting by high blast furnace.

4. *Smelting by the blast furnace.* The only kind of high blast furnace I have seen in use in England is the Piltz furnace. It is adapted for highly argentiferous ores, and either it or a modification of it is, I am given to understand, in common use in the United States. Plate XXXI.

represents this furnace, which is charged by the top opening with the ore, fuel and appropriate flux (iron in some form being essential), quite up to the top, into which an iron chimney *a* is introduced about 3 or 4 feet to catch any fume and conduct it into the flues. The reduction of the metal takes place a little above the level of the twyers *b* and the metal and slag with a regulus or matt collect in the well *c* below, from which they are run off by an appropriate arrangement which it is not necessary to describe. At the Sheffield Smelting Company's works a form of blast furnace, represented at *m*, Plate XXXII. (p. 291), is in use for smelting rich argentiferous ores. It is much lower than the Piltz, is closed at the top, from which a flue *n* to carry off fumes proceeds, and it is charged nearly to the level of the feeding opening *r*. In this particular furnace a peculiar form of water jacket has been devised to prevent the destruction of the sides in the neighbourhood of the twyers *s*. The jacket is made of cast iron, and has a number of inclined shelves *t t*, over which a stream of water flows. The cold water enters by a pipe at the top and flows away, nearly boiling, by another pipe at the bottom, and is then used for feeding a steam boiler. Omitting the water jacket, a very similar kind of furnace is in use at Snailbeach for the smelting of slags. The slag produced in the smelting in such a furnace is discharged at *u*, while the lead with its accompanying matt or regulus is tapped off at *v* from time to time into the sunken pot in front of the tap-hole.

Theory of the process.

In the processes in which iron is not employed, but in which the oxygen of the air alone is the agent for carrying off the sulphur, namely, in the Flintshire method and in smelting by the ore hearth, all the sulphur passes away into the flues in the form of sulphurous acid. In the Flintshire process the principal evolution of the acid occurs during what I have termed the second stage. In the first or calcination stage, part of the sulphide is oxidised into sulphate of lead, and, when the heat is subsequently raised for melting down in the second stage, the sulphate and sulphide re-act upon each other, the lead in both is liberated and the sulphur of both goes off as sulphurous acid—

$$PbO, SO_3 + Pb\,S = 2\,Pb \text{ and } 2\,SO_2.$$

In the ore-hearth process there is throughout an oxidising atmosphere, and according to Dr. Percy, "Both elements of the sulphide are oxidised by the blast with the evolution of sulphurous acid; but there immediately follows the well-known reaction between the resulting oxidised products of the lead and the underlying sulphide whereby metallic lead is separated, so that practically oxidation and reduction may be said to proceed *pari passu*."

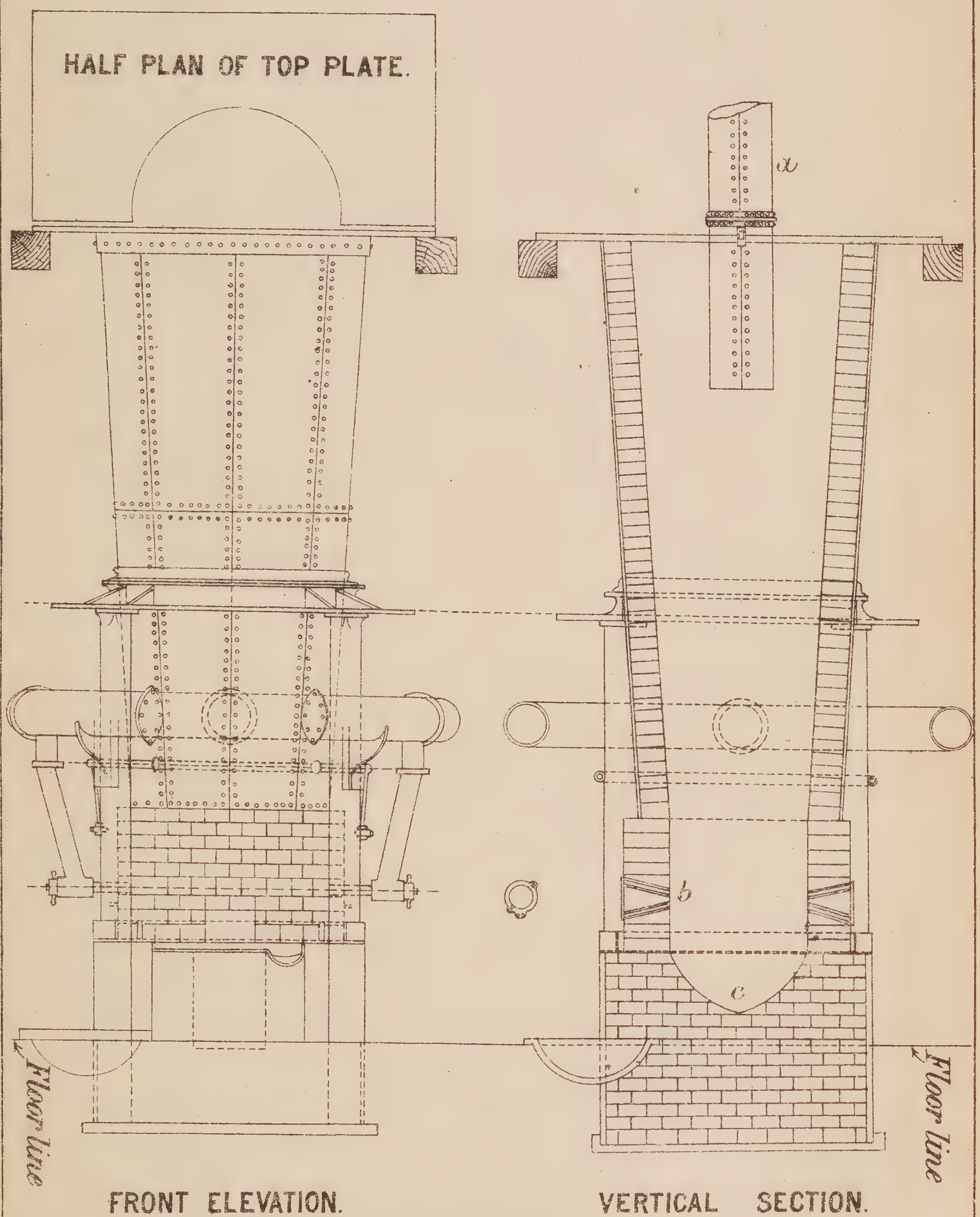
In the processes, on the other hand, in which iron is used, a part of the sulphur is taken by the iron, and does not therefore pass off as sulphurous acid by the flues; but the quantity thus taken up is but a small proportion of the whole, the actual proportion taken by it depending, in the Cornish process, upon the extent to which the calcination process may have been carried. In high blast furnaces (such as the Piltz) if the ores have not been previously calcined, nearly the whole of the sulphur in the charge combines with the iron present and enters into the matt, so that comparatively very little of it passes off from the top of the furnace in the form of sulphurous acid.

Smelting grey slag.

Grey slag from the Flintshire furnace or ore-hearth is rich in lead,—at Cookson & Co.'s works it is found to contain about 30 per cent. of lead—some of which is mechanically mixed with it, but the greater part of which is present as oxide, sulphide, and sulphate; but principally as oxide. It contains also the earthy matters of the ore with the lime used in the smelting, as well as iron and other foreign metals. These

PILTZ FURNACE.

Scale $\frac{3}{16}$ Inch = 1 Foot.



DANGERFIELD, LITH. 22, BEDFORD S^T. COVENT GARDEN.

slags have therefore to be smelted, but, as the lead produced from them is more impure than the lead obtained at the first running, they have to be smelted sepatately. At some works they are smelted like the original ore in a reverberatory furnace, but, in most of the works I have visited, in a low form of blast-furnace, termed a "slag-hearth." The precise form of the slag-hearth in use in different works varies, but virtually it is a small blast-furnace constructed of fire-brick, or else of iron lined with fire-brick, having a bottom sloped from behind forwards. The front part of the furnace is open from the bottom upwards for a short distance, and out of this opening the reduced lead and slag run out and are separated by a mechanical arrangement or filter of cinders, the slag running off above into a slag pit (sometimes containing water, which at once quenches and granulates it) while the lead passes through the cinders, and is collected in a lead pot. This furnace is charged from an opening about 1 foot above the twyers with alternate layers of grey slag and coke, and a moderate blast, usually from three twyers, is used in the smelting. The top of the furnace is closed, and a flue proceeds from it to the main flue of the works. The "black" vitreous slag produced in this furnace ought not to contain more than 1 to $1\frac{1}{2}$ per cent. of lead, and is thrown away.

Volatile products—lead fume.

I have mentioned sulphurous acid as one of the volatile products of the process of lead smelting, but beside this there proceed from the smelting furnaces, mixed with it, the volatile products of the combustion of the fuel used, and the vapours are rendered opaque by a white or grey dusty material carried off with them in large quantities. The admixture of all these things as they escape from the chimney of a lead-work constitutes a white smoke, which is less or greater at individual works according to the amount of pains taken to arrest it. Much of the solid material of the fume given off from the smelting furnaces and slag-hearth collects in the flues of the works, and being very rich in lead, is from time to time taken out and smelted, but separately from the ores, since it contains metallic impurities such as zinc, arsenic, and antimony, which render the lead produced from it hard and unfit to mix with lead produced in the earlier processes.

Mr. A. French has, in conjunction with Mr. Wilson, of the Sheffield Smelting Company's works, very carefully studied the physical nature of lead fume as it proceeds from the blast furnace used at these works.* He has found it to consist of polished spheroidal particles, very uniform in size for the specimens taken at the same time, although those taken at different times frequently differed greatly. The smallest of them were about $\frac{1}{20000}$th of an inch in diameter. After passing along a flue for about 60 feet these particles begin to aggregate into flakes, which become more numerous and larger as the distance from the furnace increases. He found the sp. gr. of the fume from his blast furnace to be about 5·5. "Assuming 1 cubic foot of smoke to contain 4 grains "of fume, which it often does, and that the size of the particles is "$\frac{1}{20000}$th part of an inch in diameter, one may find by a simple calcula-"tion the number of particles contained in a cubic foot and their distances "apart from each other." The calculation gives 43,904,712 as the number of particles in the cubic foot and $\frac{1}{30}$th inch as the distance they are from each other—a distance which is about 660 times their own diameter.

Composition of lead fume.

Mr. French (*loc. cit.*) says that lead fume appears to have no definite composition, as the proportion of its constituents varies in every specimen.

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* Chemical News, Vol. 40, p. 163.

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On Effluvium Nuisances, by Dr. Ballard.

He gives the following results of analysis of two specimens of fume proceeding from the blast furnaces at the Sheffield Smelting Company's works:—

	I.	II.
Oxide of lead - - - - -	44·80	68·35
Oxide of zinc - - - - -	4·80	1·80
Oxides of bismuth and copper - -	1·52	—
Oxide of iron - - - - -	trace	—
Sulphide of lead - - - -	—	2·25
Lime - - - - - -	—	2·63
Alumina - - - - -	10·00	5·40
Arsenic and antimony (oxides) - -	3·03	—
Sulphuric anhydride (SO_3) - - -	28·81	16·84
Insoluble silicious matter - - -	9·00	2·25
	101·96	99·52

Lead fume may also contain a little gold, and as much even as ½ to 1 per cent. of silver. When fluorine is present in the ores, or when fluor spar is used as a flux, fluoride of silicon will be present as a gaseous element in the fumes, but it will be decomposed by any watery vapour present, as it is in the flues of artificial manure works.

The following is the composition of lead-fume collected in the flues of the Bagillt Lead Works, where reverberatory furnaces are used, in 1859, the last specimen having been taken not from the flue, but from the bottom of the chimney stack ("The Metallurgy of Lead," by John Percy, M.D., F.R.S., 1870, p. 451):—

	I.	II.	III.
" Protoxide of lead - - -	46·54	62·26	46·88
Sulphide ,, - - -	4·87	1·05	—
Sesquioxide of iron and alumina -	4·16	3·00	10·00
Oxide of zinc - - - -	1·60	1·60	4·14
Lime - - - - -	6·07	3·77	6·73
Sulphuric acid - - -	26·51	25.78	14·15
Insoluble residue - - -	10·2	1·97	14·40
Carbonaceous matter - - -	—	—	3·37
	99·87	99·43	99·67"

Smelting of lead fume.

The lead exists in the fume almost entirely as sulphate, so that "the problem involved in its treatment for the recovery of the lead it contains is simply the reduction of that salt." Where the ore-hearth is in use the material is merely wetted to make it agglutinate, and is then smelted much in the same way as the original ore. Where the reverberatory furnace in in use it is smelted in this furnace. At Wass's Alderwasley Works, where poor ores and slags and various refuse matters are smelted down in a slag-hearth, more with the object of making fume (which is carefully collected) than to obtain lead directly, the smelting of the lead fume collected and subsequently stored as a pasty mass, is conducted as follows:—It is charged on to the reverberatory furnace in the usual way, and heated or calcined for about an hour with occasional rabbling, until the whole has become melted and run down into the well. This part of the operation lasts about an hour. Fine slack is then added, and the whole is pushed back upon the floor of the furnace and the heat is urged, when the lead separates and runs down into the well. The slag which forms is raked out by the doors opposite the tap hole, and is added to the matters

which are treated in the slag-hearth. The whole operation lasts about $3\frac{1}{2}$ hours, but sometimes longer. Sulphurous acid gas is given off in this process, and unless due care be taken, more or less of the solid fume which it is intended to smelt passes off with it also into the air.

Other operations which require to be mentioned are conducted at lead smelting works. The most important of these are the softening of hard lead and the separation of the silver which the manufactured lead contains, a proceeding which is termed "de-silvering."

Softening of hard lead.

The usual mode of softening hard lead, the hardness of which is mainly dependent upon the antimony and to a less extent upon the other foreign metals it contains, is to expose it in a reverberatory furnace having a cast-iron bottom to the action of a dull red heat with free access of air. The foreign metals are thus oxidised, some of the volatile oxides pass off as fume, and the remainder combine with oxide of lead formed, and with it are skimmed off as dross which is subsequently reduced, together with litharge made in the cupellation of silver, in a reverberatory or blast furnace in which it is mixed with carbonaceous matter.

De-silvering of lead.

The de-silvering of lead requires little description here. Three methods are in use in this country, viz., Pattinson's, Parkes', and the Rozan method. By Pattinson's process the lead is melted in a series of eight strong hemispherical iron pots set in a row: the pots are of such a size as to be capable of dealing with 6 to 10 tons of lead, the last pot (the "market pot") being, however, smaller than the others, and each is heated by a separate fire beneath. The lead melted in one of these pots is allowed to cool, and as it cools, lead, in great measure free from silver, crystallizes, and is removed by means of a ladle perforated with holes, through which the liquid lead strains away. The lead which remains liquid contains most of the silver. To enrich the liquid lead further the operation is repeated in another pot, and the process is repeated until a rich lead is obtained containing, say, 500 to 600 ounces of silver to the ton. The crystals of lead strained from the pots have also to be de-silverised in a similar way. The rich silver lead is then cupelled in a hearth made of bone earth, where part of the lead is blown off and collected as litharge (to be subsequently reduced with carbonaceous matter in another furnace), while part is absorbed by the substance of the cupel. Parkes' process depends upon the affinity which zinc has for silver. The lead is melted in a Pattinson pot and skimmed, and then molten zinc is added to it and stirred up with it, and, the fire being then damped, the metal is left to cool gradually. The zinc containing the silver now rises to the top and is skimmed off with a perforated ladle, and if necessary the process is repeated, no more zinc, however, being used than is requisite to combine with the silver known to be present. The zinc is then distilled off the alloy in an appropriate retort and condensed, when it can be used in subsequent operations. The Rozan process is in theory very similar to the Pattinson process, but is applicable to lead which has not been previously softened, inasmuch as it effects the softening of the lead at the same time that the lead is de-silverised. The object sought then is the enrichment of the lead by crystallisation. One great advantage of the process (which indeed is mainly that which commends it to the lead smelter) is that it performs by mechanical agency, and so at comparatively small cost, what is performed less perfectly and at great cost by hand labour in the Pattinson process. Lead being melted and skimmed in a hemispherical pot, is run off into a cylindrical pot or "kettle" of iron, where some water is run over the top and where steam is blown in below, causing great agitation during the cooling which then takes place. The lead crystallises in the pot as the cooling proceeds,

and the crust formed is broken down by hand from time to time. When the operation is believed to be completed, the enriched liquid lead is run out through a strainer by a tap hole below into a pot sunk in the floor of the works. The kettle is provided with a conical cover furnished with doors, which can be opened for manipulating the contents, and a wide iron pipe proceeds from the summit of the cover to convey the steam and fume, which consists of lead and foreign metals, to a flue which leads to a series of capacious chambers in which the solid matter is deposited, and from which the final volatile matters pass away by another flue to the chimney of the works. The matter deposited in the chambers is smelted with litharge in a reverberatory furnace.

Nuisances.

The nuisances to which the processes of lead smelting give rise vary in amount from *nil* to such an amount as renders a lead work a most disagreeable and objectionable neighbour. The nuisance may proceed from the fumes given off at a comparatively high level by the chimney-stack of the works, or at a low level from the body of the works themselves; and both kinds of nuisance are dependent for amount partly upon the nature of the materials smelted, and partly upon the care taken at the works to deal with the fume which is made.

High-level nuisances.

The high-level nuisance, as I may term it, is due to the "lead-smoke" proceeding from the stack. At some ill-conducted works that I have visited, immense volumes of white smoke are habitually discharged from the chimney, and being heavy, the fume rolls down over the top of the chimney, and quickly falls to the ground at no great distance from it, sweeping away with the wind along the surface for a mile or more. It has an offensive and sulphurous odour, and is complained of where it falls in a concentrated form about houses near the works. Such an abundant escape of heavy fume is assuredly a great loss to the smelter, since it is rich in lead that ought to be collected; nevertheless the loss is sustained just as if it were essential to lead smelting, which it is not. Mr. French tells me that at one work in Derbyshire where the reverberatory furnace is used he found one-twelfth of the lead in the ore to escape by the chimney. As the fume sweeps across the land, the solid part becomes deposited, while the acid is condensed upon the surface; it withers up vegetation where it impinges, and poisons animals which graze where the lead fume falls.

Low-level nuisance.

The low-level nuisance is mainly due to the occasional escape of sulphurous acid, and of arsenical vapour in addition when arsenical ores, fume, or slags are being smelted. I have noticed it chiefly in the case of smelting with the ore hearth or the high-blast furnace, and also as proceeding from the slag hearth, that is to say, where blast furnaces of any kind are in use. In smelting with a reverberatory furnace the fume only escapes from the doors of the furnace when from any cause the draught is defective, and then it is sometimes with difficulty that the men can work at the furnace. There is also some escape when the calcined ore and slags are drawn or run out. In the case of the ore hearth, fume may escape from the mouth of the hearth one day and not another day, the difference being due to the amount and direction of the wind. When arsenical ores are being smelted in the ore hearth, arsenical vapour is always given off when the slags are drawn out upon the forestone or thrown down upon the floor, and the offensive fume blown by the wind out of the building or rising out of it through the roof may become a source of nuisance outside. The offensive fume from the tall blast furnace escapes partly from the open top and partly with the slags as they run off. I have perceived the arsenical odour disagreeably at a distance of 100 yards from such furnaces when arsenical ores were being smelted. The arsenical odour may also be given off with the slags from the slag hearth. Work-

men exposed to the arsenical fumes within works are apt to suffer from severe headache, sickness, and even vomiting, especially on going to work early in the morning without having taken food, and some have told me that they feel "blown out." (*See also* p. 244.) Lead poisoning is also of common occurrence among the workmen when much fume escapes into the works, and this is especially the case in places where the ore hearth is used. Outside the works the only complaint of the fumes that I have heard, beside complaint of their disagreeable character, is that they sometimes produce sickness and take away appetite for food.

Prevention of nuisances.

No nuisance is created by the softening or de-silvering process which I have described.

Modes of condensing fume.

The best manufacturers take great pains to collect all the fume that proceeds from their smelting operations, so far as such fume is solid and can be collected, and they do this not only to avoid creating nuisance to their neighbours, but also, and indeed principally, because they thereby smelt more profitably to themselves, since they avoid the loss of lead that would otherwise escape into the atmosphere. The essential element of condensation or collection of the fume is a very long flue, in the construction of which it is well to make provision for retardation of the current of gases through it in their way to the chimney. Such provision may be made by giving a large capacity to the flue, by giving it an angular or zig-zag course, by interpolating large chambers which are best placed at the far end of the flue, or zig-zags (similar to those described at p. 254) in its course, by introducing baulks or mid-feathers here and there, against which the current may impinge, or by hanging within the flue such things as iron hooping, bushes, old nets, &c., upon which the solid matters may be deposited. These various contrivances are adopted at different works. Mr. French says (*loc. cit.*) that "we invariably find "the fume is most abundant wherever the gases have suffered the "greatest friction and fall in temperature. That this fact causes the "fume to settle is also proved by the increased escape into the air for "some time after the flues have been swept out. This I have proved," he says, "by a great many assays of the smoke, and it is also apparent "at the top of the chimney to the eye." At a good many works some kind of arrangement for washing or damping the fume is adopted in addition. As to the value of this, however, opinions among lead smelters differ very remarkably. Some of the largest smelters, such as Mr. Walker and Mr. Cookson, say that they are perfectly satisfied that as good results are obtainable by dry flues as by the use of water in addition; while Mr. A. O. Walker (who merely uses some steam produced by the evaporation of water in his flue) says that the damp acid gases have injured his brick chimney-shaft, through which obviously some percolation has taken place. Mr. A. French (*loc. cit.*) goes further, and says that the use of steam in the flues is positively injurious to the deposition. He tells me that he has carefully examined flues in order to determine this point, and that he has found less deposit in the parts of the flues where the steam has condensed into water than in the drier parts of the flues. The following particulars of the methods of condensation adopted at some works where the condensation is most carefully attended to may be usefully given. The figures are to be regarded mostly as approximate:—

Arrangements at Walker, Parker, & Co.'s works.

1. Walker, Parker, & Co., Bagillt, smelt by the Flintshire method. Aggregate length of flues (much of them underground) just 2 miles; for the most part 7 feet high by 6 feet wide, but in some parts they are 10 or 12 feet high. Early in their course the fume is made to pass through a number of shallow flues, at the bottom of which a layer of water is kept constantly supplied; the heated air converts some of

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this water into steam, which is carried forward with the fume. The greater part of the flue is disposed in the form of a helix, from the first part of which a branch or "relief-flue" passes away to a zig-zag of 20 rows or bendings, each of which being 14 yards long (the length of the zig-zag), gives a total of 280 yards of this arrangement. Old iron hooping is festooned upon iron rods within the flues of the zig-zag. The zig-zag terminates near the last coil of the helix. From the helix a straight flue conducts the fume up the side of the hill to the summit where there is a brick chimney-shaft 267 feet high. All that was visibly issuing from the top of the chimney at the time of my visit appeared to be a little steam. There was no nuisance from the chimney of these works.

At Cookson & Co.'s works.

2. Cookson & Co., Howden-on-Tyne, smelt with ore hearths. Formerly water condensation was used, but damage having resulted to the foundations of the works, it was abandoned and dry condensation substituted. The flues are arranged in a block and in the form of a zig-zag; five tiers of such zig-zags, one above another, having been built up, each tier consisting of five passages. The fume enters the nearest passage of the top tier, passes backwards or forwards along the five passages, and then drops down to the first passage of the tier below, and so on to the bottom. It then goes through a series of four chambers, from the last of which a straight flue conducts it up the side of a hill ("Ballast Hill") to the summit, where it terminates in a chimney 120 feet high; the height of the hill is 110 feet. Mr. Norman C. Cookson, to whom I am under much obligation for the interest he has taken in this part of my inquiry and the great assistance he has given me, has been good enough to furnish me with the following particulars of the size of the flues and chambers at Howden and the rate of passage of the fume through them:—

	Length.		Width.			Height.			Capacity in Cubic Feet.
	ft.		ft.	in.		ft.	in.		ft.
Flues -	2,610	×	4	8	×	9	0	=	109,620
Do. -	1,530	×	2	8	×	5	6	=	22,440
Do. -	180	×	4	8	×	5	0	=	4,200
Do. -	360	×	7	0	×	8	0	=	20,160
Chambers -	43	×	30	0	×	20	0	=	25,800
Do. -	27	×	15	0	×	23	0	=	9,315
Do. -	24	×	15	0	×	14	0	=	5,040
Do. -	20	×	15	0	×	20	0	=	6,000
	4,794								202,575

Mr. Cookson says that, when last tested, the volume of gases passing into the condensing flues was 926 cubic feet per minute; hence the length of time required for the gases to pass from the smelting furnace to the exit at the main chimney is 219 minutes, or 3 hours 39 minutes. The condensation here is very effectual. Mr. Cookson says that he found, as the result of testings at the foot of his chimney, that a cubic foot of the gases entering it contained $\frac{3}{4}$ grains of fume, and on some days a quantity scarcely weighable. There is no nuisance from the chimney of these works.

Mr. Cookson informs me that he has found it more economical in the long run to roast the ore before smelting it in the ore hearth, notwithstanding that this process increases the cost of the smelting 34 per cent. Especially he has found that in the case of roasted ore, his exit gases on testing them were remarkably free from (solid) fume whereas in the

case of raw ore the escaping fume was greater than that of the roasted ore, even taking into consideration the original quantities of fume made. He has given me the following particulars of the results obtained on smelting 400 tons of ore, all the same assay, viz., 81 per cent., half of which was smelted raw, and half after having been roasted. He says these particulars are quite reliable, as extreme care was used :—

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	200 tons, Roasted.	200 tons, Raw.
Lead, first fire - - - -	73·10	60·80
„ in grey slag - - -	2·50	1·80
„ in fume, hearth ends, top, &c. -	5·40	18·40
	81·00 %	81·00 %

In the case of raw ore the "hearth ends" were a large item, but *very* small and very much less in the case of the roasted ore. The proportion of fume (including "hearth ends") made is as 1, in the case of the roasted ore, to 3·28 in the case of the raw ore; but the testing of the exit gases at the chimney showed that the fume escaping was as 1 in the case of the roasted ore to 3·35 in the case of the raw ore.

3. Locke, Blackett, & Co., Wallsend, smelt with the ore hearth. The manager says that formerly at these works there was a block of flues built like those at Cookson's Works, but that, the flues having given way, they were all taken out and the block was converted into a chamber. The fume is now passed through three large chambers: the first with three divisions in it and the other two with four divisions in them, and the fume is made to pass through these chambers in succession on its way to a wooden chimney attached to the works and 85 feet high. The following is approximately the size of the chambers in feet, viz. :—

At Locke, Blackett & Co.'s works.

Height.		Length.		Width.		Cubical capacity.
50	×	46	×	15	=	27,000
65	×	33	×	27	=	57,915
18	×	54	×	54	=	52,488
						87,403

There were at the time of my visit three ore hearths at work smelting flue dust. The chimney was apparently giving issue to nothing that was visible, except some steam.

4. Mr. Yorke's Works at Pateley Bridge. (Smelt with the ore hearth.) There is in use here and has, I am informed, been in use for 24 years, an arrangement for washing the fumes. It is termed a "condenser," and is constructed of wood. There are two chambers side by side with an interval 3 or 4 feet between them, in which interval there is a platform for the use of the workman. The chambers are each about 84 feet long by 4 feet wide and about 12 feet high, standing in what is virtually a trough of water, and each is divided into 16 divisions by vertical partitions springing alternately from the roof and from beneath the surface of the water near the bottom of the chamber, the partitions springing from the top not reaching the surface of the water, those springing from below not reaching the roof, so that fume in passing through the chambers has to pass up one division and down the next in its course through the 16 divisions. At the top of each division is a colander into which water is conducted by means of a

At Yorke's works.

wooden channel above, and from which the water falls as a shower upon some brushwood, with which all but the lower part of the several divisions is filled. Any solid matter washed out of the fume collects in the water trough below. There is a provision for the water running off from the trough when it reaches a definite level. A fan is provided in the flue which conducts the fume to each chamber, and not only drives the fume through the chamber, but acts also beneficially in drawing off fume from the hoods beneath which the ore hearths are erected in the smelting-house and from the calciners. The two fans have, I am informed, been in use ever since the condensers were erected, and have not required any serious repairs until this year. From the condenser a flue, with sloping sides, 5 feet 8 inches high, 4 feet wide at the spring of the arch, and 2 feet wide at the bottom, conducts the fume to a wooden chimney $1\frac{1}{4}$ miles off. There was no work going on at the time of my visit, but the manager who has been at the works for many years told me that he was quite satisfied with the perfection of the condensation, and that whereas formerly there was great nuisance created by the works, there has been none since the present plan has been adopted. Wood, however, is an objectionable material for the condenser to be made of, since it allows of leakage, and obviously there had been some leakage from this condenser.

At Wanlock Head works.

5. The Wanlock Head Smelting Works. (Smelt with the ore hearth.) Water condensation is used here, and is very effectual. An arrangement similar in many respects to that in use at Pateley Bridge is adopted, but the condenser is erected in brickwork, which is better than wood. There is a pair of brick chambers here about 20 feet high, each divided by partitions into six divisions, over and under which alternately the fume has to pass. The water is supplied in gushes from a colander above each chamber through the agency of a tip-jack, and, instead of bushes, rows of short drain-pipes are arranged on shelves within the condenser to break up the water as it falls through. The arrangement is described in Dr. Percy's work (op. cit., p. 444). From the washer the fume passes to three chambers of wood provided within with a zig-zag arrangement and brushwood, and from these, by means of a large flue, to a wooden chimney on the top of a hill; the length of the flue is said by the manager to be 800 yards. The quantity of water used in this condenser is about 2 tons per minute. It has been found that about half of the fume is taken out by the condenser, and that the other half deposits in the long flue and zig-zags, through which the fume subsequently has to pass to the chimney. The sulphurous acid appears also to be in great measure washed out. The arrangement for the condensation is very effectual, and the result is in striking contrast with what is observable at some other works a few miles off, where none but abortive attempts at condensation appear to have been made.

At Grassington works.

6. Grassington Smelting Works. (Smelt by Flintshire method.) The flue from the furnace is $1\frac{1}{4}$ miles long, 6 feet high, and 4 feet wide, and is conducted up a hill on the moor to a chimney built of stone. It is straight in the latter part of its course, but in the early part of its course makes a circuit like a loop on the side of the hill. Two small washers are provided, each of which has two chambers, and the fume passes up one chamber and down the other. The chambers have brushwood within them, and water is thrown down each chamber alternately by means of a tip-jack like that in use at the Devon Consols Works (p. 258). One of these chambers is near the commencement and the other near the end of the flue. The condensation effected here is considerable, but not by any means complete; a good deal of fume escaped by the chimney.

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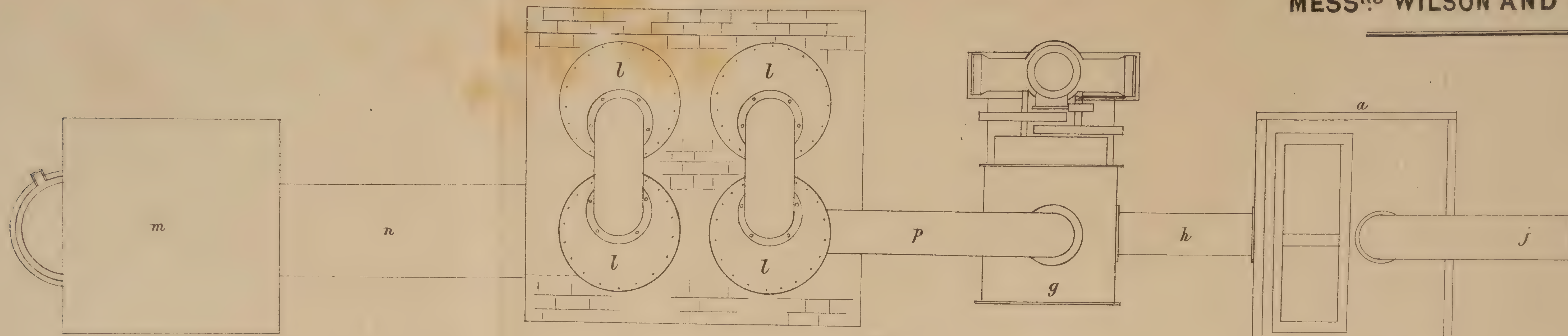
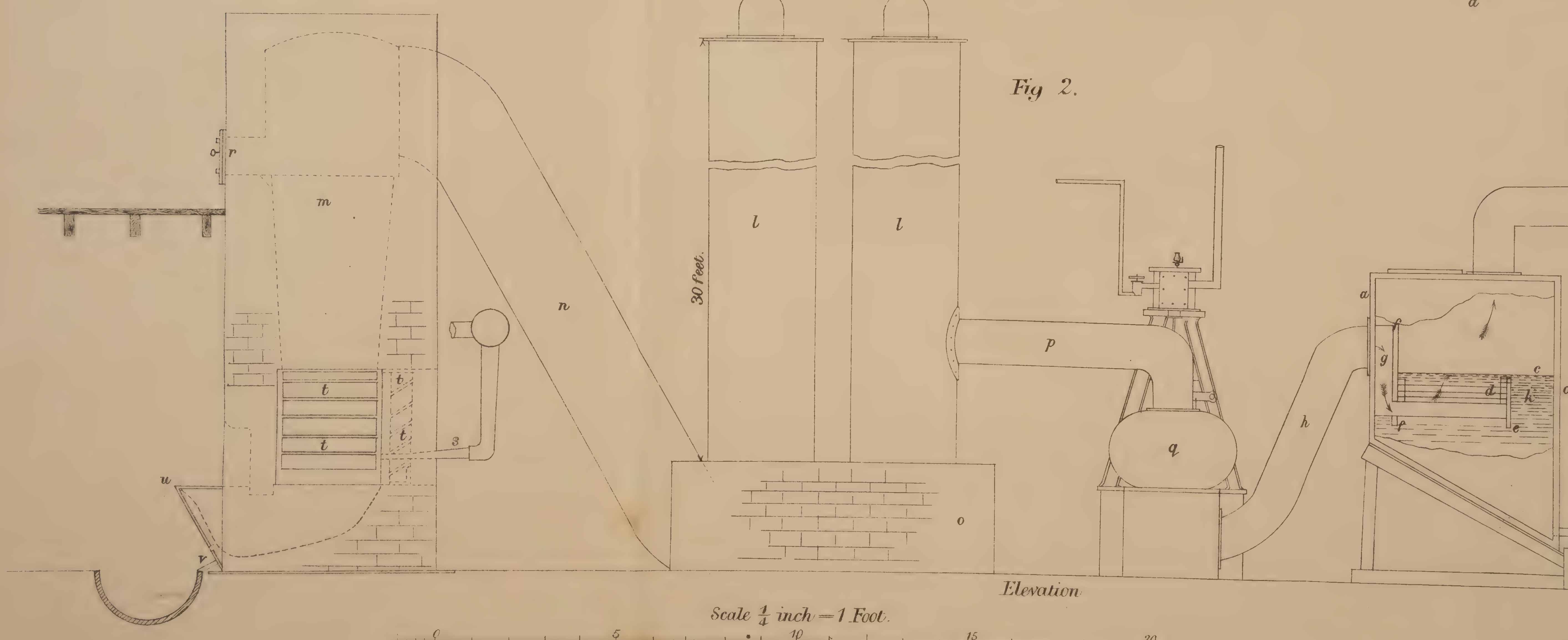
THE FUME CONDENSER OF MESSRS. WILSON AND FRENCH.

Fig 1.



Plan

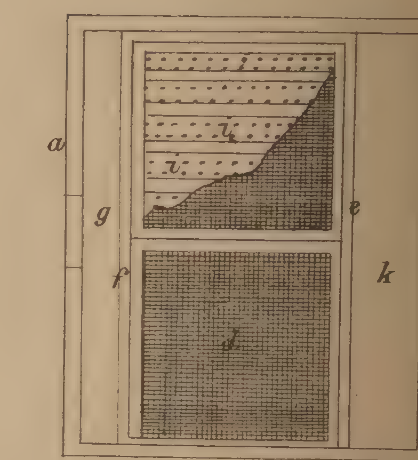
Fig 2.



Elevation

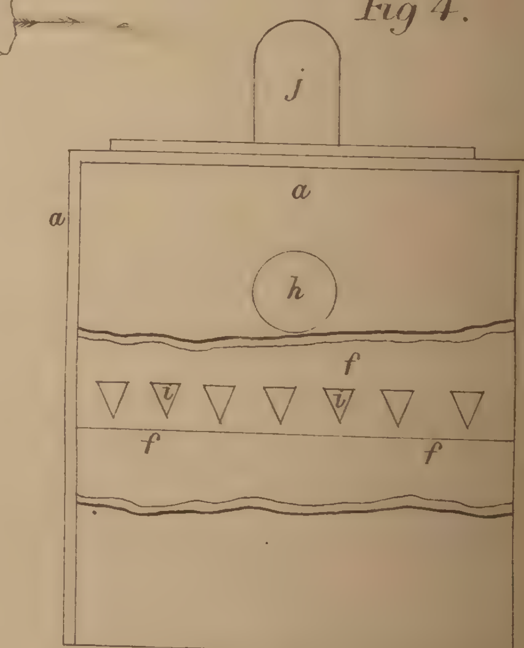
Scale $\frac{1}{4}$ inch = 1 Foot.

Fig 3.



SECTIONAL PLAN JUST ABOVE PERFORATED TUBES & SCREENS.

Fig 4.



SIDE OF BOX NEAREST BLOWER REMOVED TO SHOW PARTITION B. AND OPENINGS OF TRIANGULAR TUBES.

Dangerfield Lith. 22. Bedford St. Covent Garden.

At several other works that I visited the water condensation was little more than nominal, consisting of narrow showers of water passing here and there into the flues. It was sufficient to damp the fume with steam, but not to effect much more. Mr. French (*loc. cit.*) says: "Practical results accord well with the theory that rain drops with "their comparatively enormous surface tension are ill adapted to collect "the extremely mobile particles of fume they encounter in their descent." It is also less easy to condense the fume proceeding from a reverberatory smelting furnace than from ore hearths, since in the former case the efficiency of the smelting is dependent upon the strength of the chimney draught, while in the latter the draught need only be moderate, and the supply of air is given by a blower in just the moderate quantity requisite, and is strictly under control.

Prevention of nuisance from sulphurous acid.

But while the solid element of the fume can be arrested in the way I have described, long flues can have no influence in arresting the escape of the sulphurous acid from the chimney, and the ordinary modes of washing with water fail to remove more than a moderate proportion of it. Probably such washing will remove more of it when the ore hearth is used than when the reverberatory furnace is used, since in the former case the acid is less diluted with air. Hence it is important that the chimney in which the flue terminates should be removed to a good distance from habitations, and, if it be practicable, should be erected on the summit of some neighbouring hill.

Mr. Bolton, the manager of the works at Stanhope, told me that a few years ago he manufactured sulphuric acid from the fume at these works, conducting the gases, after condensing the solid element of the fume, into a leaden vitriol chamber. The ore hearth being employed at these works the acid was not too much diluted with air for this use to be made of it. He utilised the acid in the manufacture of manure. But inasmuch as towers could not be employed (see Sulphuric acid making, p. 175), probably more offensive effluvia were created in this way than by simply discharging the sulphurous acid into the atmosphere.

Wilson and French's condenser.

I have now to describe a method of condensation devised and patented (1878, No. 5,239) by Messrs. Wilson and French, and which I saw in use at the Sheffield Smelting Company's Works. One great advantage it possesses is that it occupies little space. The principle of the condensation lies in this, namely, that the gases from the furnace carrying solid particles of fume with them are, after due cooling, forced through water in such a way that the water and fume are brought into very close contact and thoroughly mixed; the solid element is thus effectually wetted and retained in the water, and the soluble gases are, as far as the dissolving power of the water permits, dissolved. Plate XXXII., for which I am indebted to Messrs. Wilson and French, represents the whole smelting and condensing apparatus as it stands at the Sheffield Smelting Company's Works. The condenser consists of a wooden box or case *a a*, having a shelving bottom where the solid matter arrested collects, and a tap *b* at the lowest point, by which the contents of the condenser are from time to time run off. The case is filled with water to the level of *c*. The box is fitted at *d* with a series of three or four copper wire-gauze screens, which are supported in a horizontal position between *f* and *e*; *f f* is a partition reaching from the top to a depth of 3 feet 6 inches and the whole width of the box, so as to form, with the wall of the case *a*, a broad channel *g*, into which the gases first enter from the pipe *h*. From the lower part of this channel a horizontal series of triangular wooden tubes *i i* pass forwards beneath the screens, and they are provided at the top surface with perforations through which the gases pass out from them and then through the screens (which are immersed in

the water) and water, to be finally discharged by the pipe *j* which leads to the chimney of the works. An open space *k*, formed by the side of the case and the plank *e* which supports the triangular pipes and the screens, acts as a return or overflow channel for the water which is set in motion by the ascending current of gases: this promotes the subsidence of fume to the bottom of the box, and prevents at the same time a considerable amount of saltation of the water above the gauze, which would tend to wear it out. The cooling arrangement in use at these works is represented at *l l*. The smoke from the furnace *m* passes by the wide inclined flue *n* to the bottom of the first of a series of four upright tubes *l l*, through which it passes in succession from the top of the first to the top of the second, and from this to the bottom of the third, and so on. The cooling tubes are made of boiler plates (being simply old boiler tubes), and they are placed vertically merely with the object of saving space and to facilitate cleaning, since all the fume which settles there is found in cavities prepared for its reception at the bottom of the supporting brickwork *o*. From the cooler the smoke passes through the wrought-iron pipe *p* to the blower or fan *q*, which is worked by a direct-action engine, and which forces the smoke into and through the condenser in the direction shown by the arrows. With respect to the working results of the apparatus Mr. French writes as follows:—
" The quantity of lead, silver, &c. arrested at our works amounts to " from 95 to 98 per cent. of that contained in the smoke as it leaves the " furnace, and frequently even from 95 to 98 per cent. of the metallic " contents as they enter the condenser, without taking into account that " which deposits in the flue leading from the furnace to the condenser. " These results are obtained when the smoke is made to pass through a " depth of $8\frac{1}{2}$ inches of water and three wire gauze screens. With " greater depths of water and the same number of screens as high per- " centages as 99 and 99·5 have been caught. With smaller depths, the " results are lower, but still very satisfactory. The power required to " work a condenser capable of condensing from 95 to 98 per cent. is " about 2-horse power for each ore hearth or reverberatory furnace. " Mr. H. S. Bell, F.C.S., Associate of the Royal School of Mines, was " commissioned by the Sheffield Smelting Company to test the capa- " bilities of the condenser and its adaptability to their work. He tested " the smoke immediately before it entered the condenser (station 1), " and as it left it (station 2) using the depth of water generally " employed, viz., 7 inches above the perforations of the triangular " pipes. He found that with this depth of water from 93 to $93\frac{3}{4}$ parts " per cent. of the metallic lead were arrested; he took no account of " the fume which was deposited in the flue between the furnace and the " condenser, the quantity of which usually varies from one-fourth to " one-third of the total quantity of fume which leaves the furnace. In " order to condense the remaining 5 per cent. of fume (not arrested " when 7 inches of water are used) a little extra depth of water (say " $8\frac{1}{2}$ inches), and therefore an extra blowing power would be requisite, " but this would add only about 1*s.* 6*d.* per 24 hours to the cost of " working, and the extra cost would be in many cases repaid by the " additional saving of fume." But Mr. Bell also found that the condenser was effectual in arresting the sulphurous acid contained in the smoke,—a very important point in relation to the subject of this report. He thus wrote to the Sheffield Smelting Company on August 20, 1879: " Although my attention in the course of my experiments was especially " directed to the saving of lead, still I could not omit noticing that a " large proportion of the sulphurous acid gas was absorbed by the water " in the condenser, and it was apparently not until this water was

" saturated that sulphurous acid began to make its appearance at the " second station." When the water in the condenser has become saturated with this gas, an event which would rapidly happen in cases where the condenser is used in ordinary lead smelting, the escape of sulphurous acid by the exit flue would recur. Mr. French thinks that it might all be arrested by his condenser, if instead of charging it with a definite quantity of water, a constant stream of water were made to flow through it. But under this arrangement settling ponds for the fume suspended in the effluent water would have to be provided. Other modes of dealing with the sulphurous acid escaping after the saturation of the water in the condenser may be suggested. Mr. French thinks that the gas would be arrested if the smoke washed in the condenser were made to pass up a coke tower supplied with water at the top, and perhaps this might be effectual where the ore hearth or any form of blast furnace is in use. But it may be doubted if a coke scrubber would arrest the acid when the smoke is so largely diluted with air as it is when proceeding from a reverberatory furnace. Still the use of Messrs. Wilson and French's condenser is calculated to facilitate subsequent dealing with the acid gases, and perhaps some chemical mode of dealing with them might be devised. Mr. French (Chem. News, loc. cit.) suggests that the waste gases might be " propelled by means of a steam " jet through a heating apparatus, similar to the hot blast heaters used " in iron-smelting works, and the hot sulphurous acid, steam, and air " passed through common salt according to Hargreave's patent process " (see p. 199). Other chemical agents calculated to arrest the sulphurous acid may be suggested, such, for instance, as a soluble sulphide (*e.g.*, the yellow liquor from alkali waste heaps, if available), or hydrated peroxide of iron. In the one case an alkaline hyposulphite, and in the other sulphate of iron would be produced, and both of these products have a commercial value. But it remains yet to be seen by actual working whether the condenser, which acts well in the Sheffield Smelting Company's process, is equally applicable to the ordinary processes of lead smelting. I may add that Mr. French informs me that Mr. Fletcher, of the Alkali Acts Department, has made two trials of the apparatus, one with hydrochloric acid, and the other with the vapour of common salt, and that he found that when $8\frac{1}{2}$ inches of water were used, $97\frac{3}{4}$ parts per cent. of the former and $93\frac{1}{2}$ of the latter were arrested and condensed. The condenser may thus also prove valuable for the condensation requisite in the businesses of alkali making (p. 212) and the manufacture of salt-glazed pottery (p. 80); but in order to adapt it to these trades, the materials of which the screens are made might require modification.

Prevention of low-level nuisance.

As respects the low-level nuisance proceeding from smelting-houses where the ore hearth is used, some advantage appears to be gained by the use of a sliding shutter which can be let down in front of the opening to the hearth during part at least of the operation. At several works I have seen a hood in use to catch the offensive fume proceeding from the slags when drawn forward upon the forestone, a pipe above conveying the fume to a chimney outside. With the same object, the ore hearth is at some works set back within an arched recess capacious above and similarly communicating with the outside air. But even this is sometimes inefficacious. A suggestion made to me by Mr. Norman Cookson appears therefore valuable, namely, to bring the hood well forward and to draw the air required for the blast from the upper part of the interior of it. The arrangement at Pateley Bridge, already described, shows how a fan may be usefully employed to prevent this form of nuisance.

Where iron is used to remove sulphur, whether in the Cornish method of smelting or in smelting with the blast furnace, there is of course less sulphurous acid made and therefore less to discharge into the air than when iron is not used. The iron fixes the sulphur in forming a protosulphide. But unless the matt be thrown away, which would be a wasteful proceeding, there is still a liability of nuisance being created in the subsequent dealing with it. If the matt be burned or "calcined," sulphurous acid is again formed, and must be got rid of somehow, although it is more easy to utilise it without creating nuisance when it is formed in this way, inasmuch as it need not be inconveniently diluted with air, being capable of burning by itself without any fuel.

THE MELTING OF OLD METAL.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 5, 1875	Lewis - -	Belle Isle - -	Metal washing. Tin burning.
June 9, 1876	Great Western Railway Company.	New Swindon -	Brass-founding, &c., &c.
Mar. 18, 1878	Whitaker -	Clitheroe.	—
April 3, 1879	Heaps - -	Leeds - -	Lead pipe manufacture.

Nuisances.

Now and then in the course of this inquiry my attention has been directed by health officers and others to nuisances that have been complained of as arising from works in which old metals, old iron, old brass, and old lead especially, are more or less habitually melted up. In one instance, namely, that of the Great Western Company's Works at New Swindon, a complaint of nuisance was made to the Board, and it gave rise to some correspondence. The character of the nuisance is not always apparently the same. Sometimes, as in the case of the Swindon complaint, it is a very disagreeable "metallic odour" which is complained of, at other times it is an offensive odour of another kind, due to the burning of oily lubricating matters with which the metal melted happens to be smeared, or of excremental matters adhering to the metal, as in the case of melting of old leaden soil-pipes.

Prevention of nuisance.

When old metal is foul with organic matters which produce a stink in burning, the nuisance may be obviated by first cleaning the metal from these matters with an alkaline ley or otherwise, or by conducting the offensive fumes through a fire on their way to a sufficiently tall chimney shaft. One or other of these remedies is applicable, I believe, to any case of the kind that may arise.

After visiting the Swindon Works, where the nuisance arose from the melting down of old or scrap brass in an air furnace, I reported fully upon the subject to the Board. I myself perceived the disagreeable smell complained of at a distance of 100 yards from the chimney 70 feet high, from which white vapours (partly probably of oxide of zinc) were emitted at the time, which vapours, being heavy, soon fell towards the earth. My inquiries led me to believe that the complaint that these offensive metallic fumes (whatever their chemical nature may have been) produced in the family of the complainant a depressed condition of general health, with languor, loss of appetite, headache, nausea, and

sickness was well founded. I was not prepared at the time to offer any suggestion as to the appropriate remedy for the nuisance. But I have some further information as to its mode of origin. It is well known that a peculiar metallic odour of lead pervades the interior of workshops where lead is rolled or made into pipe, and it is apparently due to the presence of lead diffused in the atmosphere. Other metals, such as tin and copper, emit an odour when rubbed by the hand. No odour, however, is perceptible as emitted in the melting of copper or in the manufacture of brass (an alloy of copper and zinc, with sometimes some lead or tin). The metallic odour such as was complained of at Swindon appears only to be emitted when *old* brass is melted down. When I was in Glasgow last November my attention was attracted by a paper on the "Solubility of Solids in Gases," which had recently been communicated to the Royal Society by Mr. J. B. Hannay and Mr. J. Hogarth, of the Annfield Chemical Works, in Glasgow. Having failed to get from other chemists any suggestion explanatory of the phenomenon I wanted explained, I consulted Mr. Hannay, who suggested that copper might in this instance be carried into the air with the products of the destructive distillation of the lacquer with which the old brass being re-smelted had, when new, been covered. He therefore kindly proposed to experiment on the subject, and the result of his first experiments was as follows :—He scraped old lacquered brass, (which gave to the hands the offensive odour which old brass gives when handled,) and dealt with the scrapings. He found the volatile matter which sublimed (from the destructive distillation of the lac, grease, &c.,) to contain copper. A little of it treated with ammonia gave a distinct blue colour. New brass did not give any such reactions, nor did the old brass after its surface had been removed by means of nitric acid. Subsequently he melted some old brass in a small furnace and washed the fume given off with water, and got both copper and zinc reactions.

THE REFINING OF GOLD.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Oct. 21, 1879	Johnson, Matthey, & Co.	Hatton Garden.	
„ 23, „	Brown and Wingrove.	Wood Street, Cheapside.	—
„ 28, „	Rothschild -	Royal Mint Refinery.	Concentration of sulphuric acid. Manufacture of sulphate of copper.
„ 29, „	Raphael - -	Thomas Street, Burdett Road, Limehouse.	Ditto.
Nov. 18, „	Sheffield Smelting Company.	Sheffield - -	Smelting jewellers' sweepings &c., and gold and silver ores.
„ 19, „	E. W. Oakes & Co.	Ditto - - -	Ditto.

Process.

The object sought in the refining of gold is the removal from it of every particle of foreign metals, such as silver, copper, lead, antimony, &c., which may be present in the gold to be refined. The process depends upon the solubility of these metals in certain hot acids which

have no solvent action upon gold. When the operation is conducted on a large scale with plenty of space for the requisite plant, concentrated sulphuric acid (oil of vitriol) is the acid employed, but under other conditions nitric acid is used. At some establishments both the sulphuric acid and the nitric acid processes are used according to circumstances, but generally only one or the other of them.

Quartation.

Neither of these acids, however, will, by any length of boiling, remove from the gold the silver which it contains in the small proportion in which that metal is present: to enable the acid to dissolve it, the proportion of silver has to be greatly increased. The first thing therefore done with the gold is to alloy it with three times its weight of silver, which contains a limited proportion of copper. This process is technically termed "quartation," and is effected by melting the silver and gold together in a coke furnace. The alloy thus made is "granulated" by ladling it out of the melting pots and pouring it into a vessel of water. The alloy or "parting metal" is then in a physical condition favourable for the action of the acid upon it. The acid portion of the operation is technically termed "parting."

"Parting" by sulphuric acid.

The Sulphuric Acid Process.—When sulphuric acid is used as the solvent the plant employed is that represented in the diagram Plate XXXIII. The granulated alloy is introduced into a hemispherical cast-iron pot *a*, about 2 or 2½ feet in diameter, which is heated by a fire beneath, and which is provided with a flat cover of sheet lead *b*, having two openings near its front part (the side nearest the workman's platform *c*). The smaller of these openings, provided for the introduction of a siphon, has usually a removable cover; the other, a larger opening used for the introduction of the materials, is usually provided with a hinged cover. There is also, proceeding from the back part of the leaden covering, a pipe *d*, made either of lead or platinum, the use of which is to convey away the vapours generated in the process. The alloy having been thrown in, oil of vitriol is added in some excess of the quantity known to be requisite for the solution of the metals in the alloy, and heat is applied. The sulphuric acid is heated to boiling, and after about one hour's heating, the solution is usually complete, the foreign metals are in solution, and the gold lies at the bottom of the pot in a powdery condition. The reaction which takes place is this: half the sulphuric acid necessary for the solution of the metals is decomposed, giving one of its three atoms of oxygen to them for their oxidation, thus reducing this proportion of the acid to the state of sulphurous acid which is evolved in the gaseous state; the other half of the acid necessary for the solution combines with the metallic oxides thus formed to form sulphate of silver, copper, lead, &c. The acid used being in excess, the liquor is still acid. Abundant and dense white acid fumes are evolved; they consist of steam, sulphuric acid vapour, and sulphurous acid. When the solution is complete, and the gold has subsided to the bottom of the iron pot, the liquor is ladled or, by means of a platinum siphon, drawn off into water contained in a lead-lined tank *e*, which is covered by a wooden cover *f*, in some works completely, and at other works imperfectly. In the former case a hole in the cover is provided, through which the long arm of the siphon is introduced. The temperature is now raised by the injection of steam through the pipes *g*. In this tank the diluted solution remains for about three hours. Being left to rest for a time a deposit of sulphate of lead, &c. occurs, and then the clear solution is drawn off by a tap near the bottom into another vessel or tank *h*, lined with lead and containing sheets of copper; this tank is open and uncovered. The liquor, as it runs from the tank *e*, is of a blue colour, due to the sulphate of copper it con-

APPARATUS USED FOR COLD REFINING WITH SULPHURIC ACID.

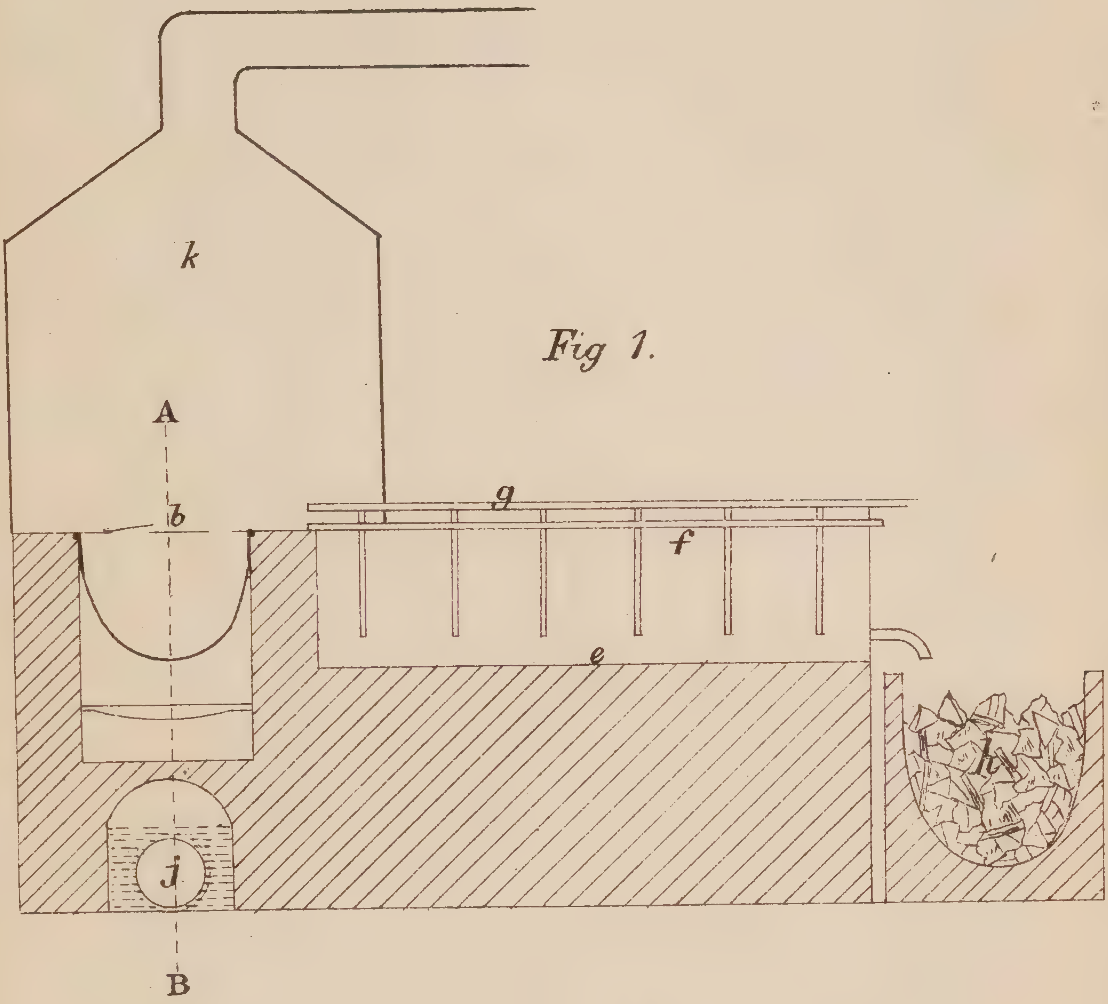
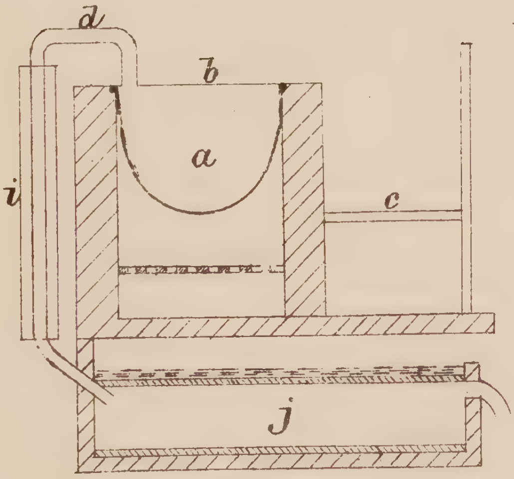


Fig 1.

Fig 2.



SECTION THROUGH A.B.

Dangerfield. Lith. 22. Bedford St. Covent Garden.

tains. The object of the copper is to decompose the sulphate of silver in solution, the result of the reaction being the solution of the copper with the formation of sulphate of copper, and the deposition of the silver of the sulphate of silver in a powdery condition. The solution of sulphate of copper is run off into appropriate tanks, and the silver, being removed, washed with water, and pressed in a hydraulic press, is melted into ingots of pure silver. The gold taken out of the iron pot is not, however, even now absolutely free from silver. Hence, to remove the last traces of this metal, the gold in the powdery condition is boiled again in a smaller pot with more oil of vitriol, the heating being continued for two hours. At small works this boiling is effected in the same pot as the first boiling. The gold is then washed with hot rain or distilled water, and subsequently melted into ingots.

The solution of sulphate of copper has now to be dealt with. It is therefore transferred to a lead-lined tank, heated by a fire beneath, where it is evaporated down, and from which it is transferred into cooling vats to crystallise. The crude salt is again dissolved and recrystallised to prepare it for sale. The rooms in which all these operations are conducted are usually lofty and capacious, and ventilated by louvres at the roof.

"Parting" by nitric acid.

The Nitric Acid Process.—In this process the granulated alloy is introduced into a platinum vessel of cylindrical form, like a show tea canister, and 18 to 24 inches high, with a wide, short-necked opening at the top, into which a stoneware pipe can be fitted to carry off the fumes generated in the process, and another opening fitted with a cover, by means of which the solution is at the end of the process poured off. At some works the platinum vessel is provided with a short spout, through which the solution is poured out, and the vessel itself is provided by pivots at the sides, which work upon iron supports, so that it may be tilted up to pour out the liquid matters. The gold alloy having been introduced, and the nitric acid added, heat is applied below, either by a coke fire or by the flame of gas. At the works in Sheffield where the nitric parting is performed on a small scale, large glass flasks heated each upon a separate sand-bath are used instead of platinum vessels. The operation of solution of the foreign metals occupies about 6 hours, during which time acid fumes are being given off. Part of the nitric acid is decomposed to oxidise the metals with evolution of nitrous fumes, part unites with the oxides to form nitrates, and part comes off with watery vapour as nitric acid. Acid fumes are given out during the whole process of solution; but the nitrous fumes are most abundant in the earlier part of the process, and nitric acid fumes at the later part. Acid fumes also rise when the contents of the platinum or glass vessel are poured out. The solution of the nitrates of silver, &c. poured from the platinum vessel or glass flask is submitted to the decomposing action of copper in appropriate wooden vessels, and the solution of nitrate of copper produced is reduced by iron or is sold to chemical manufacturers who may require it; or the impure silver solution is evaporated down and crystallised and recrystallised so as to obtain nitrate of silver in a sufficiently pure state for sale.

Nuisance.

The nuisance which has been made the subject of complaint as proceeding from the refining of gold consists in the diffusion of acid vapours into the atmosphere outside the works. Where the sulphuric acid process is adopted these fumes appear as a white vapour, which being heavy falls towards the ground about the works, and in some circumstances and conditions of weather may envelope neighbouring houses. The fumes are irritating to the eyes and to the respiratory organs, induce coughing, and according to Mr. Liddle, the Medical Officer of Health for Whitechapel, produce the greatest possible dis-

comfort to persons exposed to them. They have also been complained of as rapidly corroding brass work and as injuring furniture in neighbouring houses. Of the two acids, sulphuric acid and sulphurous acid, evolved in this process, the former is that which appears to be the chief source of the annoyance produced by the fumes. The principal source of nuisance where the nitric process is used, consists in the diffusion of nitrous fumes into the atmosphere. The odour of these fumes is distinctive, and, like those above referred to, the fumes are irritating to the organs of respiration. But so far as I have been able to learn, the sulphuric acid process is that which has been the more fruitful of complaints.

Sources of nuisance.

In the sulphuric acid process the sources from which the nuisance may arise are the following, viz. :—1. The discharge of acid vapours from a chimney not sufficiently elevated. These vapours are chiefly those which pass off from the iron pot by the pipe *d*, if due means be not taken to arrest or condense them. 2. The discharge of acid vapours from the openings at the roof of the buildings. Probably now this is the customary source of nuisance when nuisance occurs. The vapours are first emitted into the house and then pass from it through the ventilating openings into the external atmosphere at a comparatively low level. The escape of vapour into the building may be due to one or more of the following conditions :—*a*. Deficient aspiration from the iron pot, through the pipe *d*, in which case the acid vapour escapes at the openings or chinks about the cover. When a stronger heat than usual is employed, and the process is conducted more violently than usual, the evolution of sulphuric acid vapour is so great that the ordinary chimney draught may be unable to draw it all away, and a portion of the fume may thus escape into the building; or the pot may boil over. *b*. If the pot be too hot at the time that the gold is ladled from the large to the small pot, or if the latter be hot at the time, an abundance of sulphuric acid fume may escape into the workshop. *c*. The evolution of acid vapours from the hot-water tank *e*.

The sources of nuisance from the nitric acid process have been already sufficiently pointed out. It may arise from the escape of the nitrous gas generated in the process of solution or of the acid vapours that are evolved from the hot liquor as it is poured out from the platinum vessels in which the solution is made.

Prevention of nuisance, in sulphuric acid process;

It is quite practicable to obviate nuisance from such works as have been described, and this, whichever process of "parting" may be in use. As respects the sulphuric acid process, the more essential requisites for the attainment of this object are efficient means of drawing off the vapours from the pot, and the tank *d*, and proper means of disposing of them when drawn off. The draught of the chimney of the works may be used as the agent for the aspiration, or a jet of steam thrown into some convenient part of the pipe which conducts the vapours away may be used (as at p. 153), or the operation of the chimney draught may be aided and supplemented by the steam jet. But the adaptability of the steam jet will in part depend upon the method of condensing the vapour which is preferred at the individual establishment. At Rothschild's refinery and also at Raphael's, the acid vapour is condensed by means of cold, the object being to recover the sulphuric acid evolved in a condition as little dilute as possible. The method adopted is virtually the same at these two establishments. The arrangements for the first part of the condensation at Raphael's works are represented roughly in the diagram Plate XXXIII. Fig. 2. The pipe *d* is bent downwards towards the floor of the works, and in this vertical part is jacketed, cold water flowing through the jacket *i*. This pipe terminates below in a leaden pipe *j*, about 16 inches wide and 20 feet

long, which lies horizontally in a trough of cold water. From this pipe any uncondensed fume passes into a leaden chamber 10 feet long × 4 feet wide × 5 feet high, having eight curtains arranged within it, so that the fume must pass alternately up and down in the chamber while traversing it from one end to the other. It is now conducted by a long pipe arranged round the interior of the workroom to a series of three leaden scrubbers, each about 6 feet high by 3 feet wide, which are filled with large coke, which scrubbers the fume enters alternately at the bottom and the top, and from the last of which uncondensed gases pass away to a chimney 145 feet high. At Rothschild's works there are no fewer than 12 leaden chambers distributed about the works and in the cellars as room could be found for them, each being 6 feet square; the fume has to pass through the whole series and finally through three coke scrubbers similar to those in use at Raphael's works on its way to the chimney, which is about 200 feet high. The acid collected in the various parts of these condensing arrangements is strong enough to make it worth while to concentrate it for use again in the iron pot. Mr. Arnauld, the manager of Rothschild's works, says the strength of it is about 60° Beaumé. The concentration is effected at both the works mentioned by means of a cast-iron still with a leaden or platinum cover similar in form to that represented in Fig. 26, p. 174, and it is with a view to economy of acid and the utilisation of the acid saved that the method of condensation described has been adopted. The sulphurous acid gas which passes into the chimney is discharged at too great an elevation to be any nuisance. At Rothschild's works the tank *c* is closely covered down, and a pipe conveys the acid fume drawn off from it first through a condensing pipe surrounded with cold water and then into the leaden chambers; it is in fact dealt with first in the same way as the fumes from the iron pot. In another establishment the acid fumes from the pot, drawn off by means of a steam jet, are driven into a lead-lined covered tank filled with cold water, which effectually arrests the sulphuric acid: the uncondensed gases pass off from the tank into the chimney of the works. At another establishment the acid fume, first passed through a leaden pipe immersed in a trough of cold running water, is conducted through a small leaden chamber or scrubber packed with coke kept constantly wet with water, the aspirating force being the chimney draught. At both these last-mentioned establishments a use is found for the dilute sulphuric acid thus obtained. Nuisance, however, is quite avoided. Over-heating and too violent boiling in the iron pot may be avoided by duly careful working. The escape of acid during the removal of gold from the large to the small pot is avoidable by waiting until the large pot has sufficiently cooled down, and by taking care that the small pot is not much heated before the gold is transferred to it. Where the same pot is used for both boilings the fire should be drawn for half an hour before the solution is ladled out and fresh sulphuric acid is added. At Rothschild's refinery a provision against nuisance from the accidental evolution of acid fumes from the pot into the atmosphere of the workshop, is made by enclosing the part of the apparatus where the pot is situated within a leaden closet or hood *k* represented in Fig. 1, Plate XXXIII. It is glazed on one side for the admission of light, and is open on the side next the working platform. From the top a wide pipe conducts away fume which rises into it to one of the leaden condensing chambers already described.

in nitric acid process.

It is to the advantage of the refiner to save as much as possible of the nitric acid evolved during the nitric acid process. At Johnson and Matthey's works this is effected by carrying the stoneware pipe attached to the mouth of the platinum vessel into a capacious stoneware jar, shaped like a chemist's Woulffe's bottle, and from this by long stone-

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

ware pipes placed vertically and rising to the roof of the chamber, and then bent downwards, to two other similar bottles. In these bottles the greater part of the acid condenses and is collected. So much of the nitrous acid as is not condensed with the nitric acid is conducted by a pipe proceeding from the last bottle to the back part of the ashpit of a coke fire, which is always in use and always well kept up. Nuisance is thus avoided.

Part VI.—On Effluvium Nuisances arising in Connexion with Branches of Industry in which Matters of Mixed Origin (Animal, Vegetable, and Mineral) are dealt with.

PHARMACEUTICAL WORKS AND GENERAL CHEMICAL WORKS.

Establishments visited.

Establishments visited.

Date.	Name.	Locality.	Articles manufactured.
Feb. 23, 1876	Howard and Sons	Stratford, Essex -	Quinine, red oxide of mercury, calomel, precipitated sulphur, &c.
June 1, „	Ormerod & Co. -	Leeds - -	Nitric acid; sulphuric acid.
„ „	G. J. Crowther -	Ditto - -	Ditto; ditto; hydrochloric acid; nitrate of iron.
Dec. 4, „	Chapman - -	Glasgow - -	Manufacture of carbonate of ammonia from urine.
Mar. 28, 1878	Spencer Ashworth	Radcliffe, Manchester.	Nitric acid; nitrate of iron; chloride of tin; soap.
April 16, „	Thomas Whiffen -	Battersea - -	Quinine, salicine, strychnia, &c.
May 15, „	William Atkins -	Liverpool - -	Hyposulphite of soda.
„ 21, „	Pickles, Simpson, and Pickles.	Dewsbury -	Nitric acid; nitrate of iron; wood distilling.
June 3, „	T. and H. Smith -	Edinburgh -	Salicine, chloroform, nitrous ether, &c.
„ „	Duncan and Flockhart.	Ditto - -	Chloroform, sp. œth. nitr. tinctures, &c.
„ 1, „	Macfarlane -	Ditto - -	Salicine, bebeerine, sulphuric and nitrous ether, morphia, &c.
„ 17, „	Townsend -	Glasgow - -	Sulphate of ammonia, arsenio-phosphate of soda, binarseniate of soda, &c.
Dec. 2, „	May and Baker -	Battersea - -	Calomel, corrosive sublimate, red oxide of mercury, sulphurous acid, sulphuret of potassium, ether, &c.
Mar. 22, 1879	William Bailey and Son.	Wolverhampton -	Bisulphite of lime, sulphurous acid, nitric oxide of mercury, calomel, corrosive sublimate, &c.
June 24, „	Albright and Wilson.	Oldbury - -	Phosphorus, precipitated sulphur, &c.

See also lists of establishments given under the headings—
Manufacture of Alkali, 3rd Report - - p. 194
Distillation of Tar, do - - p. 137
Manufacture of Sulphate of Ammonia, do. - - p. 127
„ Aniline, &c., do. - - p. 155
„ Picric Acid do. - - p. 154

It is convenient thus to group together a number of establishments I have visited in the course of my inquiry, at which a variety of substances used in medicine or in the arts are manufactured on scales differing according to the demand for them, and according as one establishment or another has acquired a reputation for certain articles. It will appear from the list that the articles prepared at any one establishment may be heterogeneous; any one article may be prepared at one time and not at another, according as its preparation may or may not at that time be profitable; and the manufacturer may, according to circumstances, altogether drop the preparation of an article, and in place of it take up the preparation of some other that he considers will pay him better. There are plenty of such works in the kingdom. Sanitary authorities may sometimes find some difficulty in dealing with nuisances from such works. It will not be necessary to consider separately the processes employed in making all the substances mentioned above.

Nitric acid.

1. *Nitric acid* has already been mentioned as manufactured at other works visited beside those in the above list. When prepared at such works or for sale, nitrate of soda, in charges of from $1\frac{1}{2}$ to 2 cwt., is introduced into an iron cylindrical retort heated by a fire beneath, and strong sulphuric acid (sp. gr. 1·7) is run in upon it. The acid passes out in the form of vapour, and is conducted then to a series of stoneware bottles, each having two openings at the top for the reception of stoneware pipes by which they are connected, and a third opening furnished with a stopper. Seven such bottles at least are requisite: it is not uncommon to see 10 in use. The final vapour which may escape condensation in the last bottle is commonly carried off by a pipe into a flue leading to the chimney shaft of the works. The only nuisance likely to occur in this process happens when the lutings are defective or a bottle becomes cracked.

Hydrochloric acid.

2. *Hydrochloric acid* is prepared much in the same way. It is technically termed "cylinder acid" to distinguish it from the acid condensed in the towers of alkali works. The only nuisance that arises is from a similar cause to that from nitric acid making.

Chloride of tin.

3. *Chloride of tin* is prepared by acting upon tin in a copper vessel by means of heat. The hydrochloric acid vapour emitted is apt to be a great nuisance. It can be prevented from being so by drawing off the vapours and condensing them in a small coke scrubber.

Nitrate of iron, &c.

4. *Nitrate of iron* and *nitrate of copper* are prepared by dissolving the respective metals in appropriate vessels in nitric acid, with the aid of heat or by means of steam thrown in. Nitrous fumes are abundantly given off, and even when carried into a tall chimney are apt to occasion much nuisance. There are various ways of disposing of them so as to prevent nuisance while utilizing the waste vapours. In works where sulphuric acid is made they may be conducted into the vitriol chamber. This is done with the fumes from nitrate of copper making at Tennant's chemical works in Manchester; and those from nitrate of iron making might be dealt with in the same way. Mr. Townsend, of Glasgow, thus also disposes of the nitrous fumes arising from the manufacture of binarseniate of soda. Where sulphuric acid is not manufactured, various agencies may be used to absorb the fumes. I have seen solution of soda used to absorb the vapour (p. 161); in which case nitrite of soda, a valuable salt, was produced; milk of lime may be used for the same purpose. The absorption is assisted by churning the gas with the alkaline solutions; or a coke washing tower (p. 155) may be used. In any of these latter cases a chimney draught or other exhaustive arrangement may, according to occasion, be used to draw off the vapours.

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Nitric oxide of mercury.

5. *Nitric oxide of mercury* is made in a hemispherical iron pot, enamelled within, and about 18 inches wide, by the action of nitric acid upon mercury, aided by the action of heat applied by a fire beneath. As soon as the nitrate is formed the heat is pushed to the extent of decomposing it. Nitrous fumes escape abundantly, and, to prevent annoyance to the workmen from them, a salt-glazed hemispherical cover with a salt-glazed pipe attached is adapted to collect the vapours and conduct them away from the building. These vapours may be prevented from becoming a nuisance by absorbing them by any of the means just mentioned, or by conducting them into the ashpit of a coke fire well kept up.

Sulphate of mercury.

6. *Sulphate of mercury* is made as a step towards the preparation of calomel or corrosive sublimate. The apparatus used is similar to that used for nitric oxide of mercury. The fumes given off are those of sulphurous and sulphuric acids. If there be a sufficiently tall chimney shaft at the works, it may suffice to conduct the vapours into it, but, if not, nuisance may be avoided otherwise. At one chemical work that I visited, a leaden pipe, 1 foot in diameter, conveyed the fumes through two chambers in succession, one of which was 8 feet square, the other 20 feet long by 2 feet wide, 2 feet deep, each having a layer of water at the bottom. From the second chamber a leaden pipe conveyed such gases as failed to be absorbed in the chambers through a coke tower or scrubber supplied with water, and having openings above into the external air. Notwithstanding this, nuisance from the acid vapours was much complained of in the neighbourhood. Since nitrous fumes were also produced from other processes at these works, it appeared to me that they might have been utilised by conducting them into the chamber with a little steam to convert all the sulphurous acid into sulphuric, which would have been easily collected by the means in existence; while the final nitrous fumes might have been dealt with by one of the means already mentioned.

Alum cake.

7. *Alum cake.*—This is a sulphate of alumina prepared by acting upon china clay, previously calcined, with sulphuric acid. The process, as I saw it carried out at an establishment where nuisance was created, was as follows: There was a lead-lined vertical cylinder provided with a stirrer within, and into this the clay was introduced. Above it was a tank containing sulphuric acid drawn from the last vitriol chamber, and therefore containing much nitrous compounds, in which tank the acid was diluted with water. After dilution the acid was run down upon the clay, and they were mixed together by means of the stirrer, while steam was thrown in to raise the temperature to 212°. Violent action took place, with the evolution of much acid vapour. As soon as the temperature of 212° was attained, the contents of the cylinder were discharged by an opening below into a waggon run in beneath it, and in this waggon the compound solidified. The cylinder was enclosed by a wooden closet or hopper, under which the waggon was run, and from the upper part of which a pipe discharged the acid vapour through the roof of the building in which the operation is carried on. There are two sources of nuisance from this process. One consists in the escape of nitrous gas on dilution of the acid, and the other in the acid fumes emitted with steam during the mixing. The former of these sources of nuisance might be obviated by using only acid which is free from nitrous acid, and the latter in great measure by drawing off the fumes from the hopper by some exhausting arrangement, and washing them with milk of lime.

Precipitated sulphur.

8. *Precipitated sulphur.* — This is prepared by boiling lime and sulphur together in water so as to produce a sulphide of calcium con-

taining an excess of sulphur. To this solution hydrochloric acid, or, when it is intended to manufacture an adulterated article, sulphuric acid, is added, so as to precipitate the sulphur, which in the latter case comes to be mixed with sulphate of lime. In this process of precipitation large quantities of sulphuretted hydrogen are given off, which may be a great nuisance to the neighbourhood. At one work I visited it was the practice to ignite this gas with a match on the surface of the liquor in the precipitating vessel; in this case merely substituting a nuisance from sulphurous acid for one from sulphuretted hydrogen. At another work the precipitating tank is covered with an angular felted roof, having an opening in front for observing the operation, and a 12-inch pipe behind to convey the sulphuretted hydrogen to a furnace, where it is consumed. A better plan would be to draw it off by some exhausting arrangement, and to conduct it through an absorber of hydrated peroxide of iron. The precipitated sulphur is well washed with water, and then dried.

Works discharging waste acid into drains.

9. *Various processes at chemical works* lead to the production of more or less waste acid, which it is not unusual to discharge into drains leading to some public sewer. Such acids ought, for the prevention of nuisance from the drains and sewers, to be first neutralised with lime, as explained under the head of "Galvanising of Iron" (p. 248).

Quinine.

10. *Quinine.*—The cinchona bark, after having been duly disintegrated, is subjected to the action of spirit in large percolators, arranged within a building which usually has free openings in the sides or roof to the external air. The cheapest spirituous solvents are employed for this purpose, such, for instance, as methylated spirit, fusel oil, &c. From the lower part of the percolators the tincture is ordinarily run off into vats or casks arranged in another similar room; and from these vats it is pumped into stills capable of holding from 800 to 1,200 gallons, which stills are heated by a steam jacket at the bottom. When the spirit has been distilled off, the spirituous extract is run out while warm from a tap at the bottom. The spirit distilled off is condensed by a worm condenser, and used over again. The extract is dealt with in a manner which requires no notice here. The spent bark contains some spirit which it is considered worth while to save. Some water is therefore added to it in the still, after the tincture has been run off, and another distillation is performed; after which the residual water, which is not even now quite free from spirit, is together with the spent material discharged into a tank: here the woody matters settle, and are strained from the watery matters and placed in a heap, the liquid, now cold, being run off into the drains. There are two sources of nuisance from such a process as this. One is the disagreeable smell of the spirituous solvent used and distilled, due to the vapours emitted during the percolations and distillations performed escaping from the building, and the other a similar odour due to the steam escaping when the spent matters are run off from the stills. The diffusive vapours from such works are said to have not only annoyed neighbours, but to have produced nausea and vertigo. More than one such manufactory has been proceeded against for creating nuisance. There are several remedial measures capable of being adopted for the prevention of nuisance from the former of these sources. Their application is also calculated to improve the condition of the atmosphere of the buildings in which these operations are carried on, and which I have at times found so loaded with an irritating spirituous vapour, as to cause running of the eyes and uncontrollable coughing. One thing that might be done is to ventilate the whole of the workshops by means of a fan into a chimney-shaft; and another thing is closely to cover the receiving vessels, providing an escape-pipe from them to convey the

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displaced air into a flue instead of permitting it to become generally diffused in the chamber. At T. and H. Smith's works in Edinburgh, where various spirituous tinctures for obtaining active principles of drugs are distilled, all nuisance is obviated, while heat and spirit are saved, by distilling *in vacuo.* As respects the second source of nuisance, the obvious remedy is to allow the refuse matters to become cool before running them off; or, if this be impracticable, to run them off through a close channel into a covered tank, and to allow them to become cold there before dealing further with them.

RAG AND BONE SHOPS.

Nuisances from rag and bone shops.

The nuisances arising from the shops of what are called "marine-store dealers" in London are notorious, and unfortunately very familiar to medical officers of health. Such establishments are not confined to back streets, but are also often seen in large thoroughfares. Marine-store dealers in London not only purchase, store, and retail old metal of any kind, old glass bottles, old crockery, &c., but also rags of any kind, grease, and bones, indeed almost any kind of domestic refuse. These things are commonly stored within the house to the extent of its capacity, and the remainder in the back yard, where a shed is sometimes erected to protect them from the weather. When I was a medical officer of health, I have often had a difficulty in getting into the back yards of such houses without mounting over heaps of filthy rags, which obstructed passage within the shop and room at the rear. Similar establishments are found in large towns. The nuisance and the danger to health from these shops early attracted the notice of the Metropolitan Association of Medical Officers of Health, from whose report on trade nuisances I cannot do better than copy the following account of the nuisance, as given by the late Dr. C. J. B. Aldis, who was at that time Medical Officer of Health for Belgravia:—"Among the odours of "London, those emitted in rag-shops or the houses of marine-store "dealers are about the most dangerous. Such pestiferous spots con-"tain fat of the worst description, where it is kept and produces one of "the vilest stinks imaginable. Beside this, a dreadful smell proceeds "from accumulated bones, which may be perceived through the gratings "of the area, should the cellar door be left open. Again, the musty "smell from filthy rags, old clothes closely packed in the front shop and "back parlour, where perhaps some of the family sleep, may altogether "produce what has been termed a 'deadly smell,' particularly after "the house is closed at night, and every kind of ventilation stopped. "But this is not all; the fat remains to be sold, not such fat as that "used by respectable wholesale houses, which during the melting pro-"cess is endurable compared with the most offensive grease sold by the "marine-store dealer. The method of selling it requires notice. The "purchaser's open cart arrives, with open tubs containing 'kitchen stuff,' "which offends the nose of the neighbours. The cart may remain half "an hour or more while fat is being carefully scraped from one tub into "another to prevent imposition, in case the seller should have added "other ingredients in order to increase the weight. I need scarcely "say that the scraping out of these morsels from one receptacle to "another augments the nuisance excessively."

Danger to health.

Rags are also commonly sorted on the premises, and occasionally "kitchen-stuff" is melted in the back yard. No inquiries are made of sellers as to the source of rags offered for purchase; many of them are probably infected rags, and when I was a health officer I met with instances in which I was led to believe that scarlatina and other infectious malig-

nant diseases had been contracted from this source, especially in children who had been allowed to play amongst the rags and old clothes. Such stores must be a constant source of danger to lodgers and passers-by, especially when dust, arising during sorting of the rags, is carried by the wind outside the house.

In 1870, when the late Dr. Ross was Medical Officer of Health in St. Giles, public attention was forcibly drawn to the rag and bone shops in consequence of the finding of a coroner's jury that a death was accelerated by the foul effluvia emanating from such a shop adjoining the house where the death occurred.

Prevention of nuisance.

Health officers well know how inefficiently the law operates to prevent the sale of infected articles to people who deal in rags and old clothes. Now and then it happens that an offender is caught and punished, but for one such case how many hundreds every year transmit with impunity such infected things to the shop of the marine-store dealer, in ignorance or in wilful contempt of the risk of so doing! Once such things have arrived at the store, their infected nature is lost sight of, and disease propagated by them cannot thereafter be traced to its true source. The danger tc the community that proceeds from such shops as these in London, and in other places where similar establishments exist, cannot be estimated. It is in my opinion very considerable; nor do I see how it is to be reduced except by byelaws such as the Metropolitan Board of Works in London and urban authorities elsewhere are or may be hereafter empowered to make. For the nuisance from fat and bones, the Association of Health Officers considered that the proper remedy was to require that the fat should be stored in barrels with close-fitting covers, and the bones in well-tarred bags, and that both should at short intervals be removed, packed as they are, from the premises. The premises themselves should be kept clean and tidy, and the walls should be limewashed at regular intervals. The remedies applicable to grease melting, bone boiling, &c., if conducted on the premises of a marine-store dealer, will be found described under the heads of "Fat-melting," "Bone-boiling," &c., in my First Report.

THE MANIPULATION OF THE REFUSE OF TOWNS.—BUSINESS OF A DUST CONTRACTOR.

ESTABLISHMENTS VISITED.

Establishments visited.

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Nov. 23, 1875 -	Sewage Works -	Tottenham.	—
,, 26, ,, -	Corporation Yard	Water Street, Manchester.	—
Dec. 16, ,, -	Town shoot or depôt.	Plymouth.	—
May 22, 1876 -	Corporation Yard	Leeds.	—
,, 30, ,, -	Ditto - - (two yards).	Salford and Pendleton.	—
Nov. 28, ,, -	Ditto - -	Lancaster.	—
Feb. 14, 1877 -	General Scott's Works.	Saltley, Birmingham.	—
Mar. 15, ,, -	Various dust collectors' yards.	Cambridge.	—
Nov. 2, ,, -	St. Luke's Vestry dust-yard.	Macclesfield St., City Road.	—
,, ,, ,, -	St. Mary, Islington, dust-yard.	Ditto.	—

Date.	Name.	Locality.	Other Businesses or Processes conjoined.
Mar. 15, 1878 -	Corporation Yard	Water Street, Manchester.	(Second visit.)
April 1, 1879 -	Ditto (new yard).	Leeds.	—
„ 7, „ -	Corporation Yard	Rochdale.	—
„ 21, „ -	William Mead's dust-yard.	Paddington.	—
„ „ „ -	Thomas Hobbs' dust-yard.	Ditto.	—
„ „ „ -	Paddington Vestry dust-yard.	Ditto.	—
May „ „ -	William Boyce's dust-yard.	Lambeth.	—
„ „ „ -	G. Cookson's dust-yard.	Ditto.	—
„ 9, „ -	Corporation Yard	Birmingham.	—
„ 12, „ -	Col. Jones -	Wrexham.	—
June 12, „ -	Corporation Yard	Holt Town, Manchester.	—
At various times	Other yards and depôts in towns visited.	—	—

Nature of refuse dealt with.

The refuse referred to is principally doméstic refuse, matters for which no use is found, and which are accordingly cast away, usually into some receptacle kept or provided for the purpose. I use the term also as including the refuse of markets and shops, mostly consisting of animal or vegetable matters, human excrement, the dung of animals from stables, &c., and slop or mud swept from the streets. These are things which it is incumbent upon sanitary authorities to see removed from the midst of their populations. In so far as they are organic matters in a state of decay, or liable to decay, they are "filth," and their retention in human vicinity is conducive to disease. In so far as they are not organic, there is no reason to believe that they are otherwise injurious than by creating a dusty atmosphere about them when left to accumulate. I must not neglect to add, in qualification of the above remark, that the distinction between organic and inorganic matters of refuse, as they are met with in domestic receptacles for refuse, is not one practically to be relied upon, when any question arises as to the offensive or injurious character of such refuse. The two kinds of things are commonly so intermixed, that particles of organic matter become attached and adherent to the inorganic matters, and render the latter nearly as offensive and dangerous as the former, whatever attempt at separating them may be made. Further, it must be kept in mind that dust and dirt swept from houses and thrown with other refuse may contain specifically infective matters, such as the cutaneous scales from a scarlatinal patient, not to mention such things as pieces of infected wall-paper or infected woollen carpet, linen, &c. The following enumeration of things which, in addition to cinders, bits of coal, ashes, brickbats, broken crockery, and broken glass, I have picked out from the contents of London dust-bins, will sufficiently illustrate their heterogeneous character: cabbage-stalks, potato-parings, and other kinds of refuse from vegetable food (sometimes whole potatoes quite fit for food), bones, fish-bones, and entrails of birds and fish, oyster-shells, lobster-shells, dead dogs and kittens, dogs dung, bits of bread, pieces of paper, wall-paper, and lime, apparently plaster from walls, rags and bits of clothing, bits of woollen

carpet, bits of floor cloth, old shoes, old tins, such as preserved meat and lobster-tins, bits of old iron, &c.

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Collection of the refuse.

Refuse matters and filth are either removed by the servants of the local authorities or by persons who make it a business to deal in such things, and who collect them either by private arrangement with individual householders or landlords, or under contract with the local authorities: and the nature of the arrangements under which they are collected and removed affects the condition of the matters when collected for removal, their comparative freshness on the one hand or their more or less decayed, putrid and offensive condition on the other hand. Where, as for example at Rochdale, the collection is systematic and made at short intervals, the collected matters have little offensive odour, but they are most offensive when they have been allowed to accumulate and become stale and decayed, especially, of course, in warm weather.

Nuisance from mode of collection.

This is the case very remarkably in London, where domestic refuse is habitually deposited in "dustbins," which are only emptied at long intervals, rarely before they are full and often not before they are overflowing. The act of removal of the contents of these receptacles is offensive and a nuisance, sometimes an intolerable nuisance to neighbours and passers-by. The "dustcart" is driven with its partial load to the door of the house, and the dustman enters with his basket, fills it from the dustbin in the back-yard, or perhaps the front area, and tips it into the cart, repeating the process as often as may be necessary until the dustbin is emptied. According to the particular contents of the dustbin, and the length of time that they have been retained, the odour evolved is more or less offensive, and spreads in the neighbourhood of the house, while, in addition, if there be any amount of wind, stinking dust is blown into the faces of the passers-by or into the open windows of neighbouring houses. I have often wondered how a civilised community can have tolerated so long such an abominable system.

In like manner, stable-dung and cow-dung are often retained in dung-pits or heaped up against a wall until they have commenced to undergo decomposition, and then the disturbance of the material during collection and the transference of it through the streets are productive of more or less nuisance.

Modes in which collected refuse is dealt with.

There are various modes in which town refuse and filth are dealt with after collection, and some of these modes are productive of nuisance.

1. Deposition in a depôt.

1. Deposition in a "depôt."—There are many towns where this practice is pursued. The matters deposited at the "depôt" may be merely dry ashes and refuse, the contents of dry middens, or "slop" from the streets (consisting of the débris of the roadway mixed with dung and domestic or other refuse cast into the roadway or spilt upon it), or the wet and partly excremental contents of the ashpits of ashpit privies, or all of these things together. Sometimes there are yards properly arranged for the reception of these things, where they are further dealt with in one or other of the ways to be mentioned presently; but often the "depôt" is a waste piece of ground outside a town or sometimes even within the town. Sometimes a depressed piece of land which requires raising is used as a depôt, sometimes an excavation from which stone has been quarried, or gravel or brick-earth has been dug, is used for the purpose. If the town be large, and sometimes even in the case of small towns, there may be many such extemporised depôts both within and outside it. Examples of this may be seen at Newcastle-on-Tyne, and some North Staffordshire towns. When the matters deposited consists of "slop," vegetable refuse, dung, and the contents of wet middens, they are sometimes shot into a square space enclosed within an extemporised wall made of straw litter, having openings pro-

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vided below for drainage. When the liquid portion has drained away sufficiently, the whole is dug down and mixed together by hand labour into a compost. The contents of cesspit privies are sometimes also shot into such places. At Paddington, "slop" collected from various neighbouring parts of London is shot into large bins, constructed of strong timbers, which are located at the very edge of the canal. On the side next to the canal, spaces are left between the transverse timbers and filled with straw, through which the liquid part of the slop drains away; when sufficiently drained the material, much reduced in bulk by this contrivance, is carried by barges into the country.

Nuisance from deposit.

Whether a depôt such as I have endeavoured to describe shall be a nuisance or not depends first of all upon its locality. If situated at a distance from a town, in the open country, it may be no nuisance, whatever the nature of its contents may be; but if it be situated in the midst of a town or near inhabited houses at the outskirts of a town, a "depôt" cannot fail to be a nuisance. When a local authority, in the exercise of its scavenging functions, collects offensive and dangerous matter of filth from the dwellings of the inhabitants and deposits it in bulk in a place within its area, where it may become a nuisance to a part of its population, or when it allows of this being done, it is guilty of a monstrous act of inconsistency. The amount of the nuisance created by a depôt will depend in great measure upon the nature of the matter deposited, and how it is dealt with when deposited. Wet material draining through a wall of litter is specially offensive, when the liquid draining away is not conducted away at once to a gully and underground drain, but allowed to run for a distance along the surface of the ground and to form pools upon it.

Midden refuse such as has been described as forming the contents of a London dustbin, when laid, as it commonly is, at a yard or depôt in a heap of many tons in weight, is certain after a time to "heat" in consequence of the rise in temperature which accompanies the process of decay in its organic constituents. This "heating" is favoured by exposure to rain and by hot weather. Under these circumstances very offensive and ammoniacal vapours are emitted, sometimes visibly; and occasionally the heating process has terminated in ignition, and then the nuisance is much intensified. I have been informed of at least two instances of this accident recently, one at Newcastle-on-Tyne, and one near Durham. The effluvium from such heaps as these is so offensive as actually to have induced vomiting. The two most offensive heaps of town refuse laid in a depôt by a sanitary authority which I have had the misfortune to inspect were at Plymouth in 1875, and at Lancaster in 1876. The former of these was alluded to in some correspondence of the Board upon the subject of the trade nuisances in Plymouth. Where a depôt is in an open place to which the public has free access, it is not unusual for individuals as well as the town authority or its contractor, to use it, and to deposit there such things as dead dogs or cats, butcher's garbage, decayed fish, &c., irrespective of any consideration of the appropriateness of the place for the deposition of such matters: such is the result of example. I have seen boys and girls grubbing among such heaps for bits of metal, and pigs grubbing for food. In the summer time such heaps attract large numbers of flies, which entering houses in the vicinity are an additional source of annoyance.

2. Sorting and sifting at a London dust-yard.

2. Sorting and sifting of refuse.—This process, as carried out in a London dust contractor's yard, or in the yards belonging to London vestries who perform what is termed "the dusting" of their several districts, is as follows:—On a load of dust being upset from the dust-cart upon the surface of the yard, some men and boys proceed to sort it.

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They are each provided with a fork and an instrument called "a drag," which has a short handle and three cast-iron teeth set about 3 inches apart, and with these they fork and drag the heap over so as to separate from it obvious pieces of vegetable and animal refuse, bones, rags, paper, iron, crockery, and glass. These are distributed, some of them into heaps, others of them into baskets; the bones are put into a bin or heap in the yard by themselves for sale to bone boilers. The rags and paper are also usually set aside for sale, the iron and old tins are always set aside for sale, and usually also the glass, while the broken crockery, brick-bats, &c. are laid in a heap to be sold as material for making new roads. What is left consists of cinders, ashes, and little bits of unburned coal, and the next process is to sift this. The sifting is performed usually by women, who sit on or close to the heap, having one or more baskets by their side, and a riddle in their hands. A shovelful from the heap is shaken in the riddle, and, the ashes and dust having passed through, what remains upon the riddle is examined, and bones, potatoes, bits of iron, &c. not removed by the first dragging process are picked out and thrown each into its appropriate basket; the cinders and coal now remaining on the riddle are thrown on a separate heap, being then technically knowu as "breeze." The following are the terms under which the matters of a dust-heap are known technically after they are separated from one another: "soft core," *i.e.*, vegetable and animal refuse; "hard core," *i.e.*, broken crockery, brick-bats, and sometimes glass, old shoes, bits of rag, &c.; "breeze" and "ashes." The work carried on at a dust-yard is not always performed in precisely the same way even in the same yard. Thus, the first sorting is not always performed immediately the material is deposited in the yard. Sometimes large heaps of the crude material are allowed to collect and even to undergo some heating before being picked over. At other times the material, having undergone the first raking over, is heaped up until it is convenient to sift it, and such an accumulation, containing much organic matter in a state of division and decay, may heat and become very offensive. In some yards the sifting is not performed by hand, but by a riddling machine, something like that figured in Plate XXXVIII. Some dustyards are entirely open and uncovered, others are provided with sheds or partial roofing which afford shelter from the rain. Most of the yards I have visited are situated at a canal wharf, from which the soft core, breeze, and ashes are loaded on to barges which carry away these things into the country; some, however, are not so conveniently situated, and then all the material brought mixed to the yard, has, after having been sorted and sifted, to be carted away again through the streets. At some yards pieces of matting, floorcloth, old leather, and other combustible matters not included under the head of "soft core" are burned, while from other yards they are sent away in barges with the soft core.

Nuisances arising.

The manipulation of refuse above described is an offensive process, and has sometimes been the subject of complaint and of legal proceedings for the abatement of the nuisance created. The nuisance consists partly in the offensive odour given off when the heaps of refuse are disturbed for sorting and sifting, and partly in the dust which is carried out of the yard by the wind. The falling of the dust, proceeding from the sifting process, into cisterns or reservoirs of water has been made a subject of complaint. One such nuisance was in 1872 investigated by Mr. J. Netten Radcliffe, acting under the Board's instructions. The dust-yard which was the subject of complaint adjoined the reservoirs of the Southwark and Vauxhall Water Company on the south shore of the River Thames; and the dust carried from the yard by the wind became scattered over the surface of the water in the reservoirs, thus necessarily polluting it

with a material the nature of which was indefinite, but which, from its source, might at any time have contained infective material. The pollution, therefore, even if small, was of a dangerous character. In this instance the bad smell arising from the accumulations and the operation of sifting was such as in Mr. Radcliffe's case to induce nausea, and it was a source of annoyance not only on the river near the yard, but at a distance of 80 yards, and even apparently sometimes on the shore at the opposite side of the river. The heating of heaps of breeze and ashes, and the odour from accumulations of soft or hard core may also give rise to nuisance. I have also heard it affirmed that meat exposed to the effluvia cannot be kept sweet, but becomes tainted, and people residing near a dust-yard have complained to me of this.

3. Burning refuse.

3. The burning of the organic material of town refuse is another source of nuisance. Sometimes a heap of such matter is made upon the ground and set fire to, and it burns in a smouldering manner with the evolution of offensive smoke. When painted articles, such as meat-tins, painted wood or floorcloth, or when leather or other animal matters are among the materials of the heap, the offensiveness of the smoke is greater than when the matters burned are merely vegetable refuse, pieces of matting, &c. Sometimes the burning is effected in a furnace constructed for the purpose, in which case the smoke is conducted to a chimney, and then the nuisance created will in a measure depend upon the height and situation of the chimney in relation to dwelling-houses. Usually the chimneys of such furnaces are low, and the nuisance occasioned is not much less than from burning in a heap.

4. Dealing with excrement.

4. The dealing with excrement.—Under the head of artificial manures (see my 1st Report) I took occasion to refer to this subject, and to point out some modes in which excrement may be dealt with inoffensively. I recur to the subject here because the manipulation of excrement is one of the proceedings carried on at some town yards where refuse matters of a mixed character are dealt with and manipulated.

To recapitulate, the nuisances arising from the business of a dust collector or contractor, and from town yards and depôts, and from the yards of persons who collect and manipulate town refuse, consist in offensive odours and dust evolved during the collection of decaying refuse; offensive odours proceeding from accumulation of matters undergoing decay, especially when they are disturbed for sorting and sifting, or when a heap takes fire, and the dissemination of an offensive dust during the sifting process; offensive smoke proceeding from the smouldering combustion by which organic refuse is sometimes got rid of, and lastly fœcal, urinous, and ammoniacal odours arising during the manipulation of excrement.

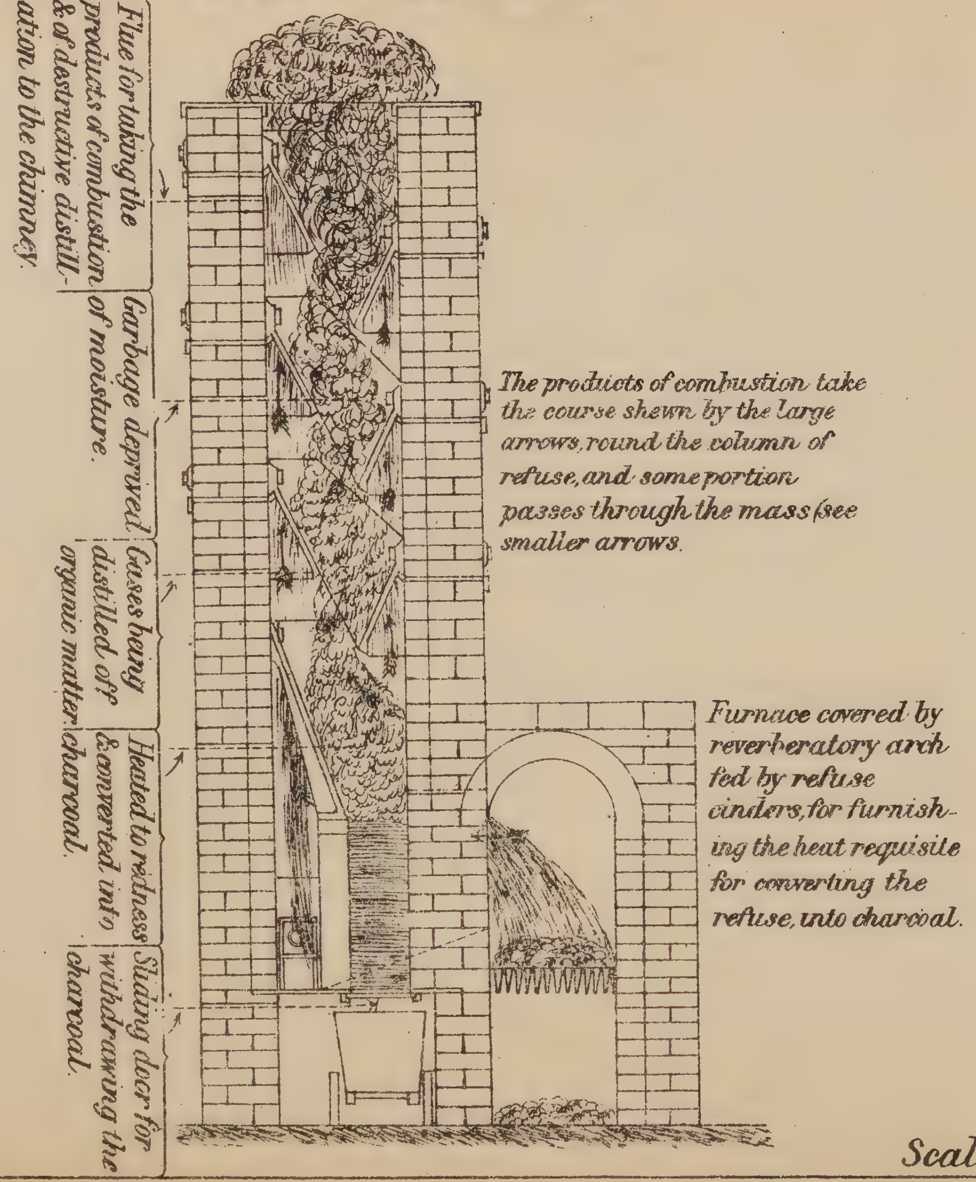
Prevention of nuisances.

As to the prevention of these nuisances :

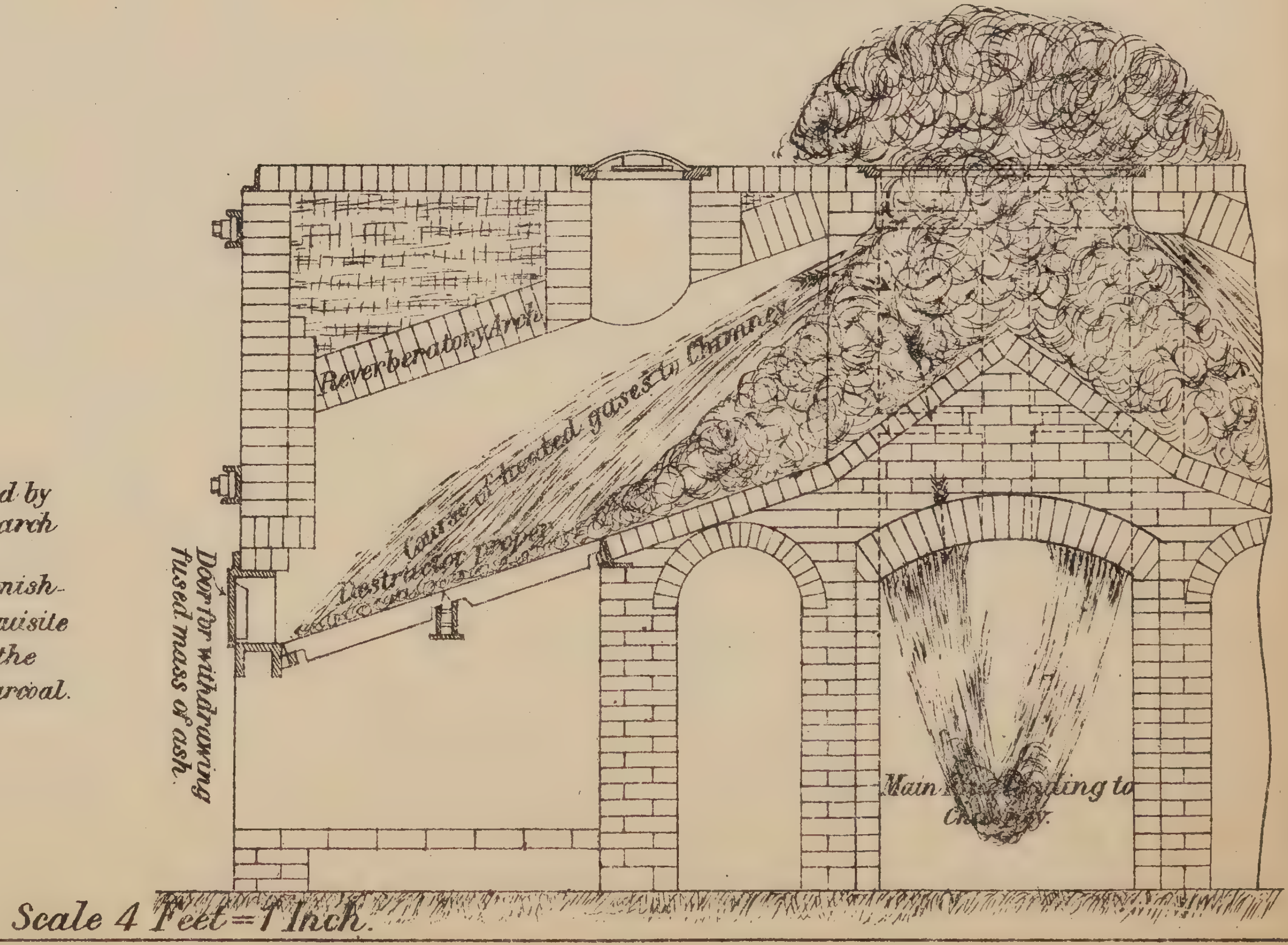
1. From collection.

1. The first observation that I have to make as to the mode of prevention of this class of nuisance has reference to the collection of refuse, and especially to the abomination of the "dusting" process as carried on in London. The system of storing domestic dust and refuse on private premises until a capacious fixed receptacle is full and a large quantity has accumulated, and then of removing it in bulk, is the counterpart of the cesspit system as applied to excrement. The condemnation and abandonment of the former is the proper sequel to the abandonment of the latter. Until in London a system of collection and removal at short intervals shall be substituted for the present system of storage and of collection at long intervals, the nuisance arising from the collection and much of the nuisance of the "dust-yards" appear to be unavoidable.

VERTICAL SECTION OF A CELL OF FRYERS PATENT CARBONISER.



FRYER'S PATENT DESTRUCTOR.



Dangerfield. Lith 22. Bedford St. Covent Garden.

2. From storing and manipulating refuse.

2. The site for a depôt should be carefully selected. A depôt should be as far as conveniently may be from inhabited houses and places where it may be a source of nuisance. Liquids draining from accumulations of wet material or slop should be made to flow speedily to a gully opening of an underground drain, that shall conduct them away and dispose of them inoffensively. Domestic and market refuse collected in towns, should not be allowed to accumulate, either in a town yard or in a contractor's yard situated in a populated part where the accumulation may become a nuisance, but should be at once disposed of in some way, either by conversion into inoffensive matter, or by removal into the open country. Sorting and sifting of dry refuse should be performed in an enclosed space or building, and in such a way that dust and offensive odours shall not escape to the annoyance of the neighbourhood. Manchester furnishes the best example of the way in which dry refuse may be manipulated without nuisance or with a minimum of offence. (See *infra.*) When dry refuse is received at a yard or depôt there should be no delay whatever in subjecting it to the requisite manipulation; and immediately the sorting and sifting have taken place, the hard and soft core, breeze, and ashes should be sent away to their several destinations in an inoffensive manner. No accumulations should be permitted upon the premises. Excuses made for accumulations occurring in London dust-yards during the winter and spring seasons of the year have reference, first, to the difficulties of collection in wet and snowy or frosty weather, when either the dust carts cannot get about, or the householders will not allow the dustmen to pass through their houses; as a result of which there are large arrears of collection, ending in large accumulations of collected material in the dustyards, as soon as collection becomes practicable, which it takes time to work off: and, secondly, in the case of yards situated at canal wharves, the asserted impossibility of barges passing along the canals when they have become frozen. The first of these difficulties is a result of the vicious system of domestic retention of refuse. Under a better system of collection there might be no necessity for dustmen to enter houses, since the dust, &c. might be brought out to them as they pass the streets daily. But even under any circumstances the excuse ought not in my opinion to be admissible, since accumulations which are offensive, or liable to be offensive if long stored, might be removed without previous manipulation into the country, and if necessary, manipulated there. The difficulty arising from the freezing of the canals is one overcome in Birmingham by the use of due means for breaking the ice, and keeping a clear passage for the boats. The same thing might, as it appears to me, be done in London. That it is worth while to adopt any available means of getting the material away appears from a consideration of the enormous quantities of refuse collected and dealt with by London contractors. One contractor, whose wharf is on the Paddington basin, stated in a recent trial that he alone sent away by canal 57,000 tons in the course of a year. The greatest quantity of material, too, is made in the winter months.

3. From burning refuse.

3. I have seen several attempts made to destroy organic and combustible refuse by burning without creating a nuisance, but for the most part they have proved failures. The forms of burners that have appeared to me to answer best are patented inventions of Mr. Alfred Fryer, of Nottingham, one of which he calls a "carboniser" and the other a "destructor." The "carboniser," which is applied to the conversion of vegetable refuse and other organic matters into charcoal, is represented in section in Plate XXXIV. It consists of a rectangular shaft or chamber of brickwork, ranged around which, in a spiral direction, is a series of iron

plates, which touch the wall at their top edges, but slope so that their lower edges are at some distance from it. The garbage is charged in continuously at the top, and sinks in the shaft as the lower portions are carbonised and removed. As it sinks, the portions which lie against the metal plates are directed to the centre of the shaft, while those already in the centre are directed against the metal plates. A fire composed of refuse cinders is maintained in an outer arched furnace; the products of combustion are led into the spiral space left between the iron plates and the wall, and emerge into a flue leading to a sufficiently tall chimney. Plate XXXIV. shows also the arrangement of Fryer's "destructor," which is used to burn up all such combustible matters as cannot be converted into charcoal in the "carboniser." The matters which are passed through the "destructor" in towns where it is in use are domestic cinders and ashes, broken crockery, &c., which are often offensive from adhering excremental or decaying organic matters. What comes out of the "destructor" are clinkers and other fused materials, which when ground down with lime have been found to make a useful mortar. The "destructor" is an arrangement of furnace fed from the back. The fire-bars slope upwards from the furnace door, and behind the fire-grate (or destructor proper) is a plain hearth also placed on an incline. The whole surface is covered with a reverberatory arch. The fire-bars having been covered with good fuel in the first instance, the refuse material is shot into the furnace at *z*. The radiant heat from the fire is reflected from the arch and intensifies the combustion; the hot gases pass over the mound of refuse *y*, which they render dry before it comes to be burned, and then pass away to the main flue behind the mass of refuse, taking the course indicated by the dotted arrows. The burning material being placed almost at the angle of repose is brought forward in the furnace with ease. The clinkers are removed at the furnace mouth. Each cell of a "destructor" will deal, it is asserted, with 140 cwts. of refuse in 24 hours. At Leeds, where not only ashes and broken crockery, sometimes mixed with excrement and urine, but also old boots, shoes, bones, shells of oysters &c., and a good deal of vegetable refuse are disposed of in the "destructor," the heat generated is used to heat a boiler for the production of steam power, and thence any smoke is conducted to a chimney 84 feet high. The smoke is no nuisance; it is moderate in quantity, and has but little offensive odour. The Sanitary Officers of Leeds say that they are quite satisfied with the inoffensive manner in which the combustion is effected by Fryer's appliances. At Birmingham the smoke from the "destructor" is discharged by a chimney 120 feet high. Some of the smoke, sucked out through a hole in the chimney, I found to have very little offensiveness of odour.

4. Arrangements for dealing with collected matters:

4. Lastly, I propose to describe the arrangements in use at Manchester, Birmingham, and Rochdale for dealing with human excrement when collected in pails, and also with domestic refuse; since they furnish illustrations of modes in which nuisances may be avoided.

in Manchester;

a. The New Corporation Yard at Holt Town, Manchester.—To this yard about half of the excrement collected in pails and of the domestic refuse of the borough is brought, and here it is disposed of according to its character. The yard is situated in a very open part of the borough, on the side of a canal, by means of which matters which are converted on the premises into useful products can be carried away into the country for use by the farmers. In the yard there is an extensive and well-constructed building, having three floors, the lowest of which is on the level of the yard and opens on to it. There is a raised road leading to the level of the topmost floor, by means of which the carts bringing the excrement, ashes, &c. enter the building. Plates XXXV.

To face Page 313.

Manchester Corporation Sanitary Works Holt Town Views of Machinery.

Riddling ashes &c from Rubbish Boxes, previous to being used as Fuel for Boilers.

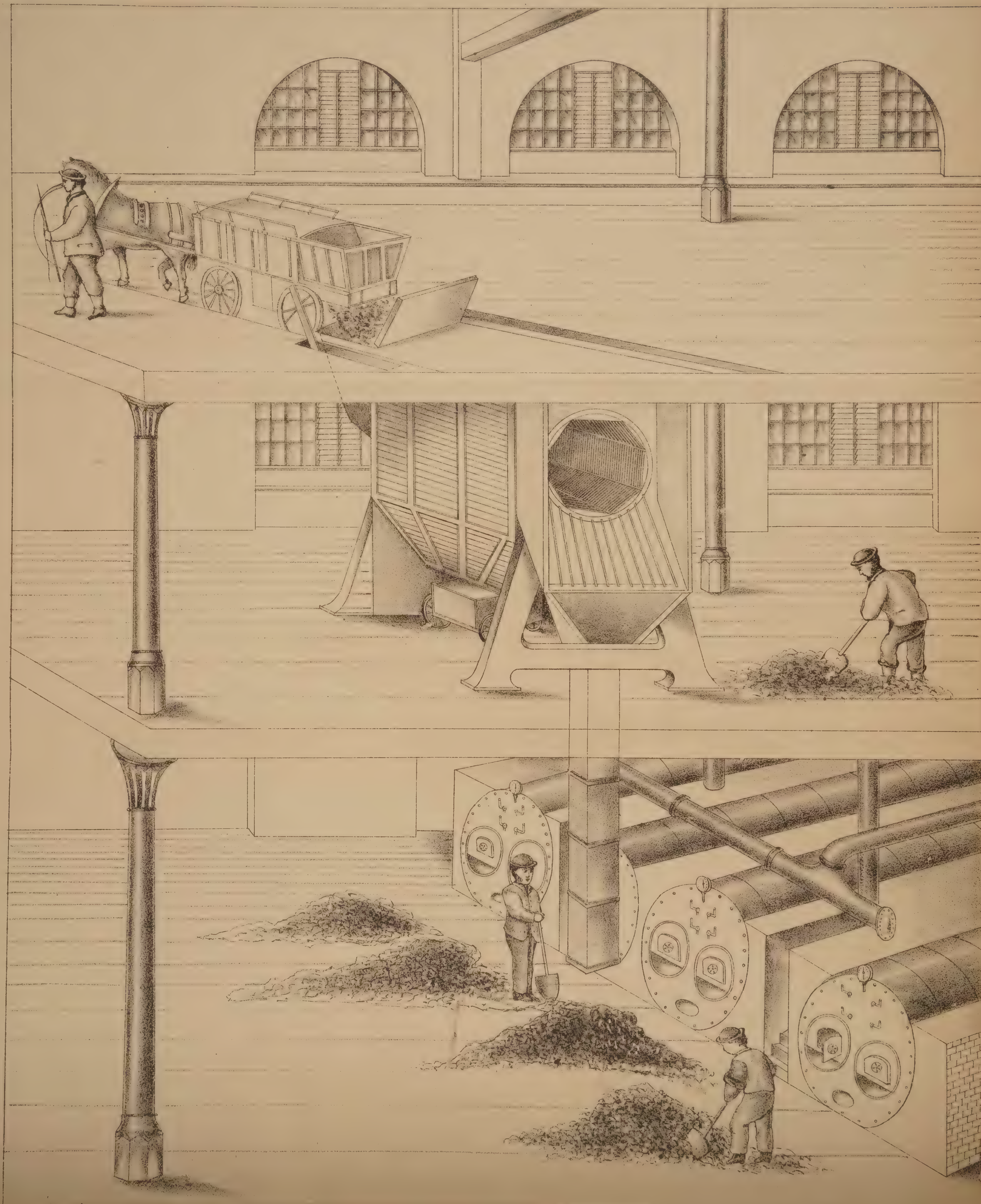
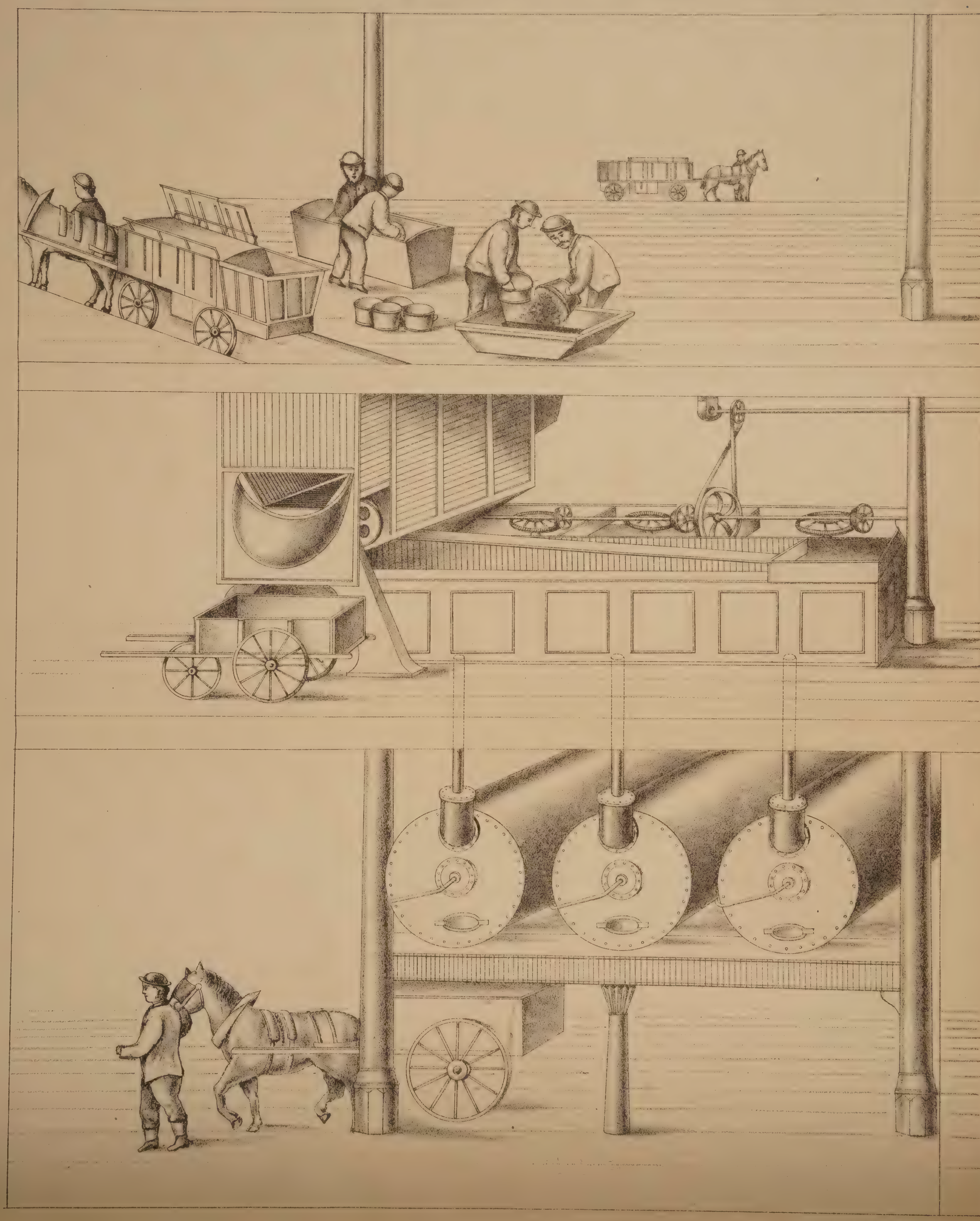


Plate XXXVI. *To face Page 313.*

MANCHESTER CORPORATION SANITARY WORKS HOLT TOWN VIEWS OF MACHINERY.

Separating the Excreta thro' Riddle into Agitating Tanks, afterwards supplied to the Poudrette Machines.



and XXXVI. are from drawings, furnished to me by the Health Committee, showing the arrangements on each floor for receiving and dealing with the matters received. A cart, on arriving at the first floor, runs along it upon a tramway leading all round the floor. It first arrives at a shoot, represented in Plate XXXV., down which the ashes, &c. are shot from the back part of the cart; thence it passes to a part of the floor represented in Plate XXXVI., where the pails of excrement are emptied by hand down another shoot; and thence the cart, after having been loaded with clean pails, passes on out of the building. 1°. The ashes and dry refuse matters discharged down shoot (Plate XXXV.) fall into a sifting and sorting machine, situated on the floor below. The riddle is, as represented, enclosed within a wooden box or screen, which extends from the floor to the roof, the only part which is open being the extremity at which the final matters which cannot pass through the riddle are discharged from it. In this way the the diffusion of dust is prevented. The riddle is cylindrical in form, placed in an inclined position, and the upper end is closed by a fixed plate around which the upper rim of the riddle works as it rotates on its long axis by means of machinery. It is through this upper closing plate that the shoot from the upper floor discharges the material into the riddle. The dust or fine ashes which pass through the riddle are received in a waggon placed below, the crocks, &c. are shot out on to the floor, where they are collected and whence they are conveyed, together with the fine ashes, to the mortar mill for conversion into mortar; while the cinders, vegetables, and other combustible matters pass down a shoot on to the floor below and close to the mouth of the boiler furnaces, in which they are burned and thus utilised. The larger and more easily separable organic matters which pass down the shoot are (if necessary) separated and loaded into barges. I understand from Mr. Leigh, the Medical Officer of Health, that up to a late period there has been a sufficient amount of combustible matter in the dry refuse collected to work all the machinery of the establishment. 2°. The first part of the arrangement for dealing with the excrement is similar to the above. Passing down the shoot (Plate XXXVI.) on the first floor, the excrement enters a riddle, similarly arranged and enclosed, on the floor below. Such of the pail contents as will not pass through the riddle (such things as cloths, crocks, &c.) are shot out at the lower end into a waggon placed to receive them. The excrement which passes through this riddle is received below in a close wooden channel, which conducts it into one of a series of iron tanks on the same floor. These tanks are covered with boards. When a tank has been duly filled, a workman pours into it a definite quantity of sulphuric acid, the acid actually used being waste acid from nitro-benzole making (p. 157). At present (the arrangements not being quite complete) there are no means provided for dealing with the offensive vapours arising from such a mixture, but it is intended to provide for their being disposed of inoffensively. From the tank the excrement is discharged into a "concentrator" on the ground floor. Each tank is of such a size as to contain a charge for one concentrator, and is so situated on the floor above that its contents can be run easily into the concentrator it belongs to. In the corner of the bottom of each tank is an opening fitted with a plug, and a pipe leads from it to the concentrator. There are on the ground floor nine concentrators corresponding with nine tanks on the second floor. The "concentrators" are fixed iron cylinders, raised sufficiently from the ground to allow of a cart passing beneath them. Each of the cylinders is provided with a steam jacket, and there are within scrapers so arranged upon arms passing off from a rotating axis as to scrape in succession all parts of the interior of the cylinder. The

axis and its arms are all hollow and filled with steam. There is a tube with a tap on it for admission of air. From each concentrator a wide pipe (not shown in the drawing) carries off offensive steam generated to a 12-inch iron main pipe leading to a powerful fan which draws off the vapours, mixed with such air as is allowed to enter the concentrator, and drives them to a washing tower of brick, down which a shower of water falls. Such of the vapours as are not condensed pass away to be discharged from a chimney shaft 230 feet high from the ground level of the works, and 160 feet high from the top level of the works. The dried excrement is discharged hot from a man-hole at the lower part of the cylinder into the cart placed below. The poudrette is laid in a heap under an open shed, and is inoffensive when cold. This hot discharge into an open cart is not a thing to be imitated, since offensive vapours pass off. The second or intermediate floor is entered by stairs from either the floor above or the floor below, and is ventilated by side windows and louvres. I perceived no offensive odour outside the building, and none within it, except upon the second floor. Mr. Leigh says he has heard of no complaint of nuisance outside.

in Rochdale;

b. The Rochdale Corporation Yard is less complete in its arrangements. The building, within which the operations are all conducted on the ground floor, is ventilated by louvres in the roof and by wide open doors at opposite sides. The ashes and dry refuse are not brought in by the same carts that bring the pails of excrement, as they are at Manchester, but by different carts; they are sorted and sifted, and the vegetable matters, cinders, &c. which are not sold are used as fuel for cylindrical boiler furnaces. One of the boilers has a furnace placed at each end, the flue passing off beneath the middle of the length of the boiler; these furnaces are stoked alternately, and in this way a good deal of the smoke is consumed. The flue leads to a chimney about 100 feet high, not quite high enough for the locality.

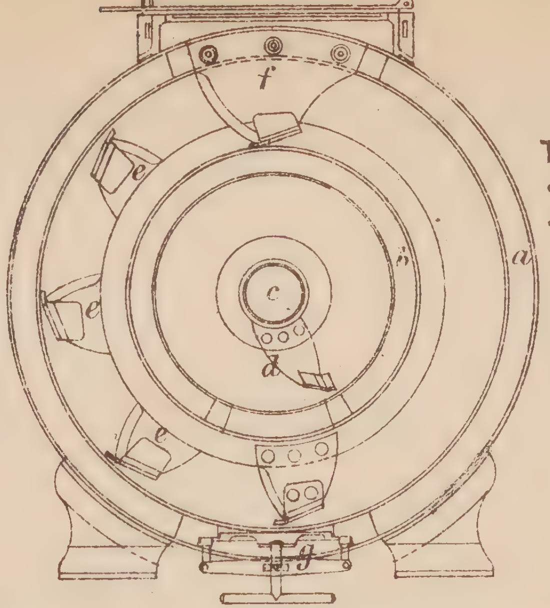
At the time of my visit the pails containing the excrement were carried by hand up some steps to an elevated platform, where their contents were poured through an opening in the top of an iron vessel which was steam jacketed. Sulphuric acid (sp. gr. 1·8) was then added, in amount about equal to $1\frac{1}{4}$ per cent. of the excrement, and the whole was stirred up by a mechanical stirrer until the bulk of the material was reduced about one ninth. The contents of the vessel were then run down by pipes into a cylindrical vessel below, the essential part of the construction of which is shown in Plate XXXVII., the drawings of which were kindly furnished to me by Mr. Alderman Taylor, the energetic chairman of the Health Committee. It is a modification of Firmin's patent apparatus. It consists of two steam jacketed cylinders *a* and *b*, one within the other, the outer one being fixed while the inner one is made to revolve, and of a fixed shaft *c*, to which are attached two spiral scrapers *d*, which scrape the interior of the inner cylinder *b* as it revolves. Other scrapers *e* are attached to the outside of the inner cylinder so as to scrape the interior of the outer cylinder *a*, and upon the inside of the outer cylinder are attached scrapers *f*, so as to scrape the outside of the inner revolving cylinder *b*. As the inner cylinder revolves, the scrapers attached to it scrape the interior of the outer cylinder, while its own exterior is scraped by the scrapers attached to the immovable outer cylinder. At the same time the interior of the inner cylinder is scraped by the scrapers attached to the immovable central axis. The offensive vapours generated both in the upper and lower vessel are condensed by passing them through iron pipes laid in a trough of cold running water, and such as fail to be condensed by this means are conducted to the ash-pit of one of the boiler fires. The excrement is thus evaporated to the consistence of a thick

Plate XXXVII.

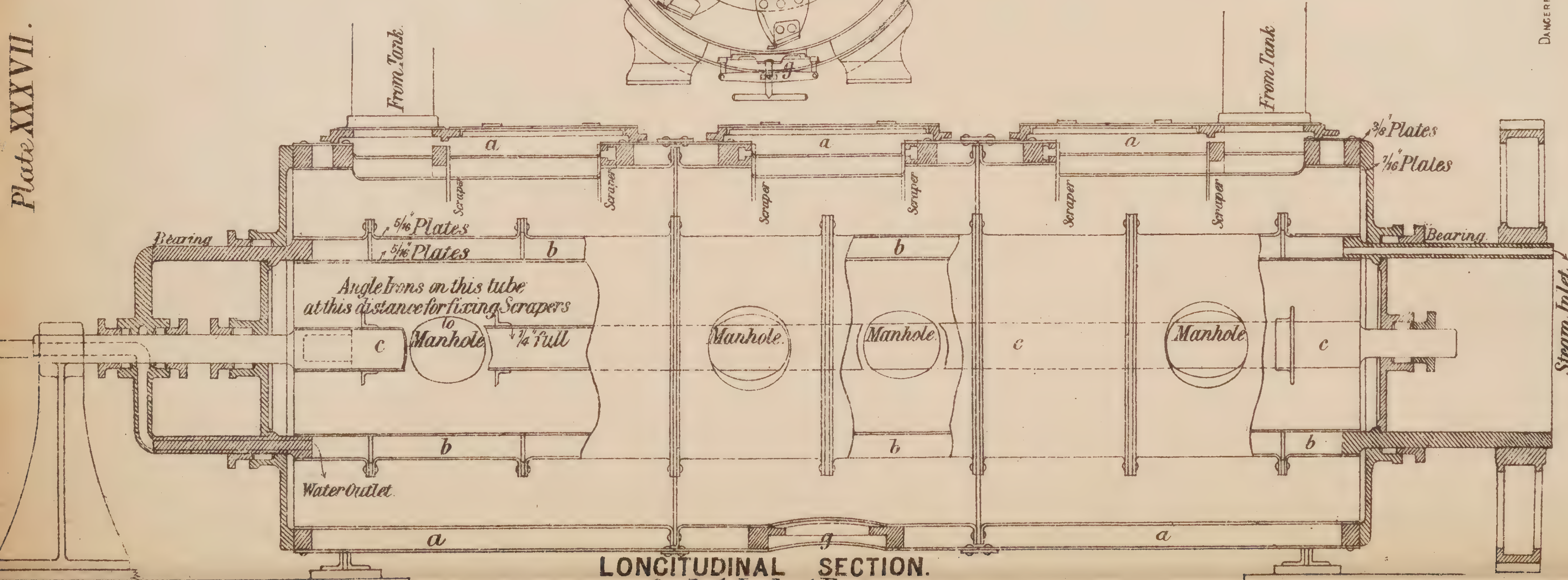
To face Page 314.

CONCENTRATOR FOR EXCREMENT,

Used at Rochdale.



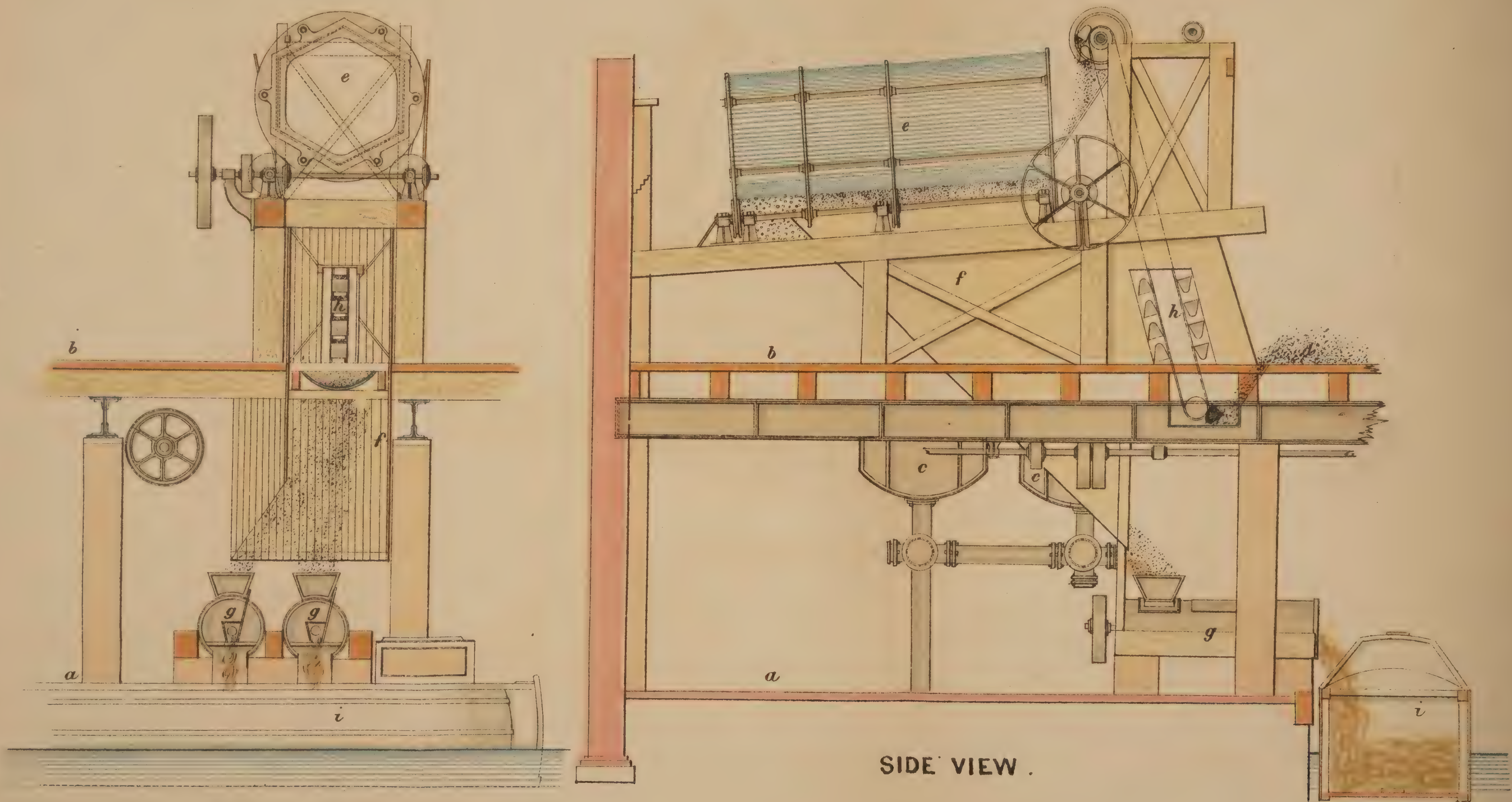
TRANSVERSE SECTION.
Scale 3 Inches = 7 Feet.
Shewing arrangement of Scrapers.



LONGITUDINAL SECTION.

Dangerfield Lith. 22. Bedford St. Covent Garden.

SIFTING AND MIXING MACHINERY IN USE AT THE CORPORATION YARD AT BIRMINGHAM.



END VIEW.

SIDE VIEW.

Scale, $1/8^{th}$ of an inch – 1 foot.

Dangerfield Lith. 22, Bedford St. Covent Garden.

mud, in which condition it is run hot out of a man-hole *g* at the bottom of the cylinder into barrows, and wheeled away to a heap within the building where it consolidates. The atmosphere within the building is more offensive than that within the building at Manchester, partly because the building is less capacious and less freely ventilated, and an offensive odour was disagreeably perceptible at a little distance outside the works on the day of my visit to them. Mr. Taylor informs me that since my visit the upper mixing vessel has been dispensed with.

in Birmingham.

c. The Birmingham Corporation Yard at Shadwell Street. There is here a very capacious building enclosed on all sides, having two floors, the lower one, Plate XXXVIII., *a*, being on the level of the canal, and the upper one *b* being nearly on the level of an adjoining street, from which the building is approached. There are stairs leading from the upper to the lower floor. There are two openings in the upper part of the building, one by which the carts enter from the town and quit the building, and another into an open yard at the side. In the lower floor there is a low opening through which boats are floated in from the canal. The carts bring in both pails of excrement and dry refuse to the upper floor. The pails are emptied here into a shoot provided with bars to keep back large matters, such as brick-bats; the excrement passes from the shoot along a pipe which conveys it to storage tanks *c c*, situated near the roof of the lower compartment. When the pails are all emptied, the shoot is washed down with water by means of a hose, and the cart proceeds to the dust-shoot *d*, where the dust is shot down, and where the coarser pieces of vegetable matter, tins, &c. are picked out by hand for conveyance into the open yard. The arrangements for sifting are shown in the drawing. They consist of an elevated cylindrical revolving riddle *e* which separates the fine ashes from the larger cinders, and both from still coarser matters which will not pass through the riddle at all, but are shot out separately from the open lower end of the riddle on to the floor, whence they are gathered up and conveyed to the yard. The ashes shot down are carried up to the riddle by means of a "Jacob's ladder" or endless strap to which little buckets are attached. The fine ashes pass down a wooden shoot *f* to a mixer *g*. The mixer *g* is cylindrical and slightly inclined, and has at the top a hinged door, which is closed during mixing, and a central revolving axis furnished with arms attached to it at such an angle that, while they effect the mixing, they push on the contents of the cylinder towards the outlet. Into this mixer are run simultaneously and continuously fine ashes from the riddle and excrement from the tanks, the proportion of the latter being regulated by appropriate arrangements. These are well mixed together in the mixer and discharged into a barge *i* moored alongside. The mixture is of softish consistence, and has only a trifling ammoniacal odour due to the action of the alkaline matters of the ashes upon the ammoniacal salts of the excrement. The coarser matters, brick-bats, pieces of iron, crockery, &c., are sorted out in the open yard (which Dr. Hill, the Medical Officer of Health, tells me there is an intention of covering in) and are set aside for sale, while the cinders and other combustible matters are consumed in a Fryer's "destructor."

Incidental Remarks on the Difficulties experienced by Local Authorities in dealing with Offensive Businesses.

Inquiry in this direction was not included within my instructions, but a brief enumeration of some of these difficulties, as they have incidentally come under my notice, may be usefully appended to this Report.

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

Difficulties arising from ignorance of trade processes, &c.

Some of them have been experienced by myself and by the authority I served formerly as Medical Officer of Health. The difficulties referred to fall under three categories. First, there are those which proceed from ignorance of the modes in which trade processes are conducted, of the sources from which offensive effluvia arise in the course of these processes, and of the modes in which the nuisances which are the causes of complaint may be reduced or altogether prevented. From time to time the Board's assistance has been sought by authorities who were in difficulty in this way. It is to be hoped that one result of my labours under the Board's instructions will be to dispel some of this ignorance.

Unwillingness of Medical Officers of Health to certify injury to health.

Secondly, there is a difficulty which sometimes arises from the unwillingness of the Medical Officer of Health to certify that a trade effluvium complained of is "injurious to health." Such unwillingness is practically fatal to any effort to procure the abatement of a nuisance under the powers given to Sanitary Authorities by the Nuisances Removal or Public Health Acts. It is quite true that other certificates to the same effect, such as certificates from two medical practitioners, or from ten inhabitants, will legally suffice to move the authority to action; but the awkwardness of an authority acting upon such certificates, under such circumstances, must be obvious when it is considered that their own officer may be compelled to appear for the defence. On several occasions I have been requested to define the term by Medical Officers of Health who felt that they could not, with the definition which they themselves put upon it, give the requisite certificate. They did not feel themselves justified in certifying that an offensive effluvium was injurious to health, if it merely occasioned such temporary functional disturbances as may be referred to the impression made upon the senses by almost any seriously offensive smell (1st Report, p. 118). It was my practice, when it became requisite that I, as a Medical Officer of Health, should give a certificate under such circumstances, to certify simply in the words of the statute, viz., that the offensive place was "a nuisance or injurious to the health of the inhabitants of the neighbourhood."* The Third class of difficulties arises out of the condition of our

Difficulties arising from condition of legislation.

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* An important judicial interpretation of these words has been recently given in the Exchequer Division of the High Court of Justice. The Local Board of Malton had taken proceedings under the Public Health Act against the Malton Farmers Manure and Trading Company for nuisance arising from the manufacture of artificial manure. The Local Board appealed against the decision of the justices, who had dismissed the summons. "The questions of law for the opinion of the Court were: "First. Was it necessary on the part of the appellants to prove as part of their "case, not only that a nuisance was caused by the effluvium, but also that it was "injurious to the health of the inhabitants of the district? Secondly. If the "Court should so decide, then did the appellants sufficiently prove the effluvium "to be 'injurious to health' within the meaning of the statute, by evidence that "some nausea that was felt was probably caused by it, and that it would make sick "persons within its influence worse, though in the opinion of the principal medical "witness it was not actually injurious to health.—Kelly, C.B.: I should be sorry "to put a construction upon this Act of Parliament which would prevent traders "from carrying on their business in a reasonable way, with reference to the rights "of their fellow creatures. But I am of opinion, on the facts disclosed by this "special case, that the appellants are entitled to our judgment. That which must "govern our decision is the language of the 114th section of the Public Health Act. "Looking first, however, at the 113th section, it is clear that the object of this group "of sections, under the heading 'offensive trades,' was to regulate noxious or "offensive trades, businesses, or manufactures. The 114th section enumerates "various places used for carrying on various trades, but includes in general words "any place used for any trade, business, process, or manufacture causing effluvia. "If such a place is certified to be a nuisance or injurious to health, not of the "inhabitants generally, but of any of them, complaint is to be made, and an inquiry "is to be held whether the business carried on is a nuisance, or causes any effluvium

legislation upon this subject. *a.* Prior to the passing of the Public Health Act, 1875, the 27th section of the Nuisances Removal Act, 1855, was applicable to the suppression of certain kinds of trade nuisances in any place not without the limits of any populous district. But the Nuisances Removal Act is now only applicable within the Metropolis, and the 114th section of the Public Health Act (which corresponds to the 27th section of the Nuisances Removal Act) has operated to deprive the Sanitary Authorities of populous places, not being within the jurisdiction of an Urban Authority, of the power to deal with such nuisances as these, which they could have dealt with formerly. There are many populous places, villages, for example, as large as small towns, and much larger and more populous than many places possessing Urban Sanitary Authorities, which (unless the necessary urban powers are obtained by them under section 276 of the Public Health Act) are left to bear this class of nuisances without any legal remedy. *b.* There are trade nuisances, in respect of which most Medical Officers of Health would not hesitate to certify that they are injurious to health, which the Metropolitan Authorities and Urban Sanitary Authorities, acting respectively under the powers given by the Nuisances Removal and Public Health Acts, find a diffi-

APP. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

38 & 39 Vict. c. 55.

Exemptions from operation of Nuisances Removal and Public Health Acts.

" which is a nuisance or injurious to the health of any of the inhabitants of the " district. The question is whether, on the facts before us, it appears that the " effluvium found in this place is a nuisance or injurious to the health of any of the " inhabitants of the district. The 6th paragraph of the case states that a nuisance " had been proved to exist, and it is not necessary that there should be an injury to " the health of the inhabitants generally. The Act requires that there should be an " injury to the health of some of the inhabitants, and that, the 6th paragraph shows, " is the case. For in answer to the second question, I am clearly of opinion that " any effluvium such as that complained of, which had the effect of causing any " person who is ill to become worse, is within the Act. The effluvium is the " gravamen of the grievance complained of, and that has caused sick persons to " become worse. It is clear that this comes within the strict words of the Act as an " injury to health, and the second question must be answered in the affirmative.— " STEPHEN, J.: There are two questions reserved by the justices. To the first of " them I answer that it was sufficient to prove that the manufacture being one " causing effluvium, such effluvium was a nuisance, whether causing injury to health " or not. The four sections commencing with the 112th, relate to the subject of " offensive trades, some of which are enumerated and others dealt with by general " words. The 114th section speaks of effluvia which are a nuisance or injurious to " health, and it is said this must be read as if it ran 'a nuisance injurious to health.' " I do not think that is its meaning, and it obviously is not its literal meaning. The " way in which it is sought to show that it is its proper meaning, is by reference to 18 " & 19 Vict. c. 121, and the case of the *Great Western Railway Company* v. *Bishop* " decided on the construction of the 8th section of that Act. That decision, regard " being had to the subject-matter of it, seems to me to come to this (a principle " which is contained in part of the judgment of the Lord Chief Justice), that the " word 'nuisance' cannot there be taken in its fullest sense, as that would lead to " some obvious absurdities. It is said then that, in the Act in question, the word " must be restricted to nuisances affecting the public health, because that was the " object of the Act, and must not be extended to nuisances with which it was not " the intention of the Act to deal. Applying that principle to this enactment, it " seems to me that in these sections the word nuisance must mean any nuisance " connected with the carrying on of any offensive trade specified, and that the " diminution of comfort thereby is one of the nuisances included in the Act. I am " not convinced by Mr. Cave's argument as to the analogous section of 18 & 19 " Vict. c. 121, because the sections under this heading 'offensive trades,' in the Act " we are now considering, are complete in themselves. In the view I take it is not " necessary to decide the second question, but on this point I quite agree with my " Lord. On a fair construction of the language used in the case, I think it is shown " that sick persons might suffer in their health, and that is an injury to health. I " will only add that it seems to me that the kind of smell which makes sick people " worse must interfere with the vigour and vitality of those who are well; but at " all events it is sufficient to show that sick persons are injured thereby."—(Law Reports, 4 Ex. D. 302. See also 40 L. T. (N. S.) 755: 27 W. R. 802.)

App. No. 6.

On Effluvium Nuisances, by Dr. Ballard.

culty in dealing with, because they are not *ejusdem generis* with those specially mentioned in the 27th section of the former Act and the 114th section of the latter Act. Such, for example, are the serious nuisances which arise from the manufacture of super-phosphate manure or sulphate of ammonia, and those which arise from chemical trades generally, except in so far as the effluvium which is a nuisance is due to some accumulation or deposit such as is referred to in section 8 of the Nuisances Removal Act and section 91 of the Public Health Act. Both Acts specially exempt from their operation those trades which can be defined as a "smelting of ores or minerals;" the Nuisances Removal Act (section 44) further exempts trades which consist in the "manufacturing of the produce of such ores and minerals" (an exemption of very wide application), and the Public Health Act (section 334) the "calcining, puddling, and rolling of iron and other metals." The exemptions mentioned are, in the case of the Nuisances Removal Act, absolute; but in the case of the Public Health Act the exemptions are not absolute—the Act is not so to be construed "as to obstruct or interfere with any of such processes respectively." I do not wish it to be inferred that I regard it as a desirable thing to facilitate legal interference by local authorities with all the businesses believed to be exempted; but I have from time to time heard complaints that local authorities tolerate such nuisances even when they are injurious to health, the complainants not having been aware that the Local Sanitary Authority in some cases had not the power to interfere, even if desirous to do so. *c.* Section 113 of the Public Health Act enables any Urban Authority to make byelaws with respect to offensive trades "established with their consent," in order to prevent or diminish the noxious or injurious effects thereof. But Urban Authorities have no such power in respect of similar trades for the establishment of which their consent had neither been required nor obtained. Such power to make byelaws is useful, if only as being calculated to prevent irritating litigations; and I cannot help thinking that, if at any time it be proposed to amend the law in respect of offensive trades, it might be worth while to consider whether this power of making byelaws in respect of offensive trades might not be advantageously extended. *d.* Difficulties have in some instances arisen in obtaining convictions for nuisance proceeding from trade accumulations and deposits, in consequence of the operation of the *proviso* in the 8th section of the Nuisances Removal Act and the 91st section of the Public Health Act. The proviso is this, viz.: "That a penalty shall "not be imposed on any person in respect of any accumulation or "deposit necessary for the effectual carrying on any business or manu-"facture, if it be proved to the satisfaction of the court that the "accumulation or deposit has not been kept longer than is necessary "for the purposes of the business or manufacture, and that the best "available means have been taken for preventing injury thereby to "the public health." In my own experience as a Health Officer, this difficulty has chiefly arisen in dealing with accumulations of domestic refuse matters in dust contractors' yards and in brickfields. At dust-yards the business consists in separating the accumulated matter into its several elements, hard core, soft core, breeze, ashes, &c.; and at some seasons the accumulation becomes so large that a long period of time must elapse before it can all be dealt with in this manner, and all this time fresh material is being added, and other fresh accumulations of the matters separated from the original accumulation are being made, each of which fresh accumulations may be as offensive as the original heap. The defence in such cases has been that the original accumulation complained of no longer exists, or that the accumulation has been

38 & 39 Vict. c. 55, sect. 113.

Provisos in 18 & 19 Vict. c. 121. sect. 8, and 38 & 39 Vict. c. 55. sect. 91.

sifted, &c. as speedily as circumstances permitted. It has been found practically impossible to upset this defence. In the case of the nuisance from Coventon's dust-yard at Battersea in 1872, upon which Mr. Radcliffe reported to the Board, the *proviso* referred to was fatal to the success of a prosecution instituted by the Board of Works of the Wandsworth District. The clerk to that Board, in a letter he addressed to Mr. Radcliffe, suggested that an appropriate remedy for the dust-yard nuisance in the metropolis would be to license dust-yards in the same way that slaughter-houses and cow-sheds are now licensed. Mr. Radcliffe, in his report to the Board, stated that this suggestion appeared to him to be of importance. In brick-yards, offensive accumulations of ashes, heated and steaming from the decomposition of the organic débris mixed with them, are still more slowly dealt with in the prosecution of the business. Practically it is found impossible to effectually deal by any process of deodorisation with accumulations which are daily or frequently being disturbed for the purposes of the business.

Concluding Remarks.

I now bring to a conclusion this inquiry which the Board imposed upon me in 1875. I am aware of its many imperfections, but I have spared no effort to render it as complete as circumstances and my own capabilities (supplemented, in the later stages of the inquiry, by the help afforded me by Mr. C. Tookey, whom the Board sanctioned my retaining as a chemical assistant) permitted.

In the progress of the inquiry I have visited more than 850 separate trade establishments, distributed over nearly all parts of England and Wales, and a few of them in Scotland and Ireland. In very many of these establishments, if not in the majority of them, more than one offensive process was being conducted. It is worthy of being recorded that, during the whole course of the inquiry, I have only on five occasions been denied the privilege of inspecting works that I desired to inspect. These were all works of comparatively small magnitude, and the denial was capable of explanation on the ground that the proprietors had within a recent period been prosecuted for nuisance by the local authorities, or had been irritated by the injudicious interference of their technically uneducated officers. In all the other instances my visits, on my explaining their object, were welcomed; and not only so, but the proprietors of the works themselves or their managers conducted me through their works, and took infinite pains to explain fully to me the details of their processes; and they freely, and some of them repeatedly, discussed with me in the most unreserved manner points of chief importance to my inquiry. Eight out of the twelve photographs with which my reports have been illustrated are from negatives taken for me at the expense of the proprietors of works; and, of the other illustrations, nearly all (with the exception of some diagrams which I made myself) are from drawings similarly supplied. All the more important articles have been read in proof and corrected in their technical details by distinguished manufacturers, whose names I have already mentioned in notes to the text of each report. This was a most important aid, as ensuring a technical accuracy which I could not have hoped to attain otherwise. It would occupy some pages were I to name, as I had intended to do, all those gentlemen who have assisted me in various ways, as, for example, by introductions to manufacturers and by valuable information. I hope others who have helped me will not consider that their services have been forgotten or have been received unthankfully,

if I mention especially the following gentlemen, viz., J. Lowthian Bell, Esq., M.P.; A. Hussey Vivian, Esq., M.P.; J. Corbett, Esq., M.P.; C. M. Campbell, Esq., M.P.; Alexander Redgrave, Esq., C.B., and Robert Baker, Esq., C.B., Inspectors of Factories; Dr. Angus Smith, F.R.S., and his coadjutors in the Alkali Acts Department, Mr. A. E. Fletcher and Mr. G. E. Davis; Mr. W. C. Roberts, F.R.S., of the Royal Mint; Mr. Provost Swan, of Kirkcaldy; Frederick Field, Esq., F.R.S.; Dr. Percy, F.R.S.; Mr. Dick, formerly of Bagillt Lead Works; Dr. Arlidge, of Stoke-on-Trent; Dr. Hodges, Dr. C. D. Purdon and Mr. Michael Andrews, of Belfast; Mr. McTear, Dr. L. Mayer, Dr. Adams, and Mr. J. B. Hannay, of Glasgow; Dr. D. B. Hewitt; Mr. Vickers, and Colonel Statham, of Manchester; Mr. C. F. Burnard, of Plymouth; Mr. Henry Doulton, of Lambeth; Dr. Bernays, F.C.S.; Dr. Russell, F.R.S.; Mr. E. W. T. Jones, F.C.S., of Wolverhampton; H. Neumann, Esq., J.P., of Northwich; Mr. J. Stevens, of Macclesfield; Mr. Alderman Taylor, of Rochdale; Mr. Alderman Burgess, of Warrington; Mr. Grocutt, of Bilston; Mr. J. Glover, of Wallsend; Mr. Norman C. Cookson, of Newcastle; Mr. Colquhoun, of Tredegar; Mr. J. Ray Eddy, of Skipton; and Mr. Chance, of Oldbury. From many of these gentlemen I received much personal kindness. Everywhere the Medical Officers of Health assisted me in my inquiry. To the following gentlemen I am especially indebted for very valuable introductions, and for the large portion of time they devoted to me when I visited their several districts: Dr. Sedgwick Saunders, of the City of London; Dr. Littlejohn, of Edinburgh; Dr. Russell, of Glasgow; Dr. Cameron, of Dublin; Dr. Taylor, of Liverpool; Mr. Leigh, of Manchester; Dr. Tatham, of Salford; Dr. A. Hill, of Birmingham; Mr. D. Davies, of Bristol; Mr. E. Davies, of Swansea; Dr. Goldie, of Leeds; Dr. E. Seaton, of Nottingham; Mr. Spear, of South Shields; Mr. Turner, of Portsmouth; Dr. Butterfield, of Bradford; Dr. McNicoll, of St. Helen's; Dr. F. Ogston, of Aberdeen; Dr. Roden, of Droitwich; Dr. Parsons, late of Goole (now of the Medical Department of this Board); Dr. Barry, of Settle; Dr. G. Willis, of Monmouth; Dr. G. S. Elliston, of Ipswich; Dr. Carpenter, of Croydon; Dr. Anningson and Dr. Armistead, of Cambridge; Mr. J. F. Holden, of Hull; and Mr. T. Drake, of West Ham. To all these gentlemen that I have named, to the manufacturers and to others too numerous to mention, who have in various ways furthered the objects of my inquiry, my own thanks and those of the Board are due. Without the help I have received, especially had I not had the hearty co-operation of the manufacturers, my inquiry must have proved abortive. I confess that, when I commenced the work, I did not anticipate so much assistance.

No. 7.

On Cases of Sickness, &c. in the Adelphi Horsehair Factory, Glasgow, by Dr. Russell.

REPORT by Dr. JAMES B. RUSSELL, Medical Officer of Health for Glasgow, on certain CASES of SICKNESS and DEATH occurring among the WORKERS in the ADELPHI HORSEHAIR FACTORY, GLASGOW, in MARCH and APRIL 1878, with REMARKS upon the COMMUNICATION of ANIMAL POISONS by MEANS of HAIR.*

IN order to account for the defects which will be apparent in the details of the cases of sickness and death among horsehair-workers, which form the basis of the following report, it is in the first place necessary to give the history of the circumstances under which they were investigated.

On 7th March 1878, I received a letter marked "Private," directing my attention to a report current on the south side of the river Clyde, that several sudden and mysterious deaths had taken place among the workers in the Adelphi Hair Factory (Messrs. John Fraser and Sons), Govan Street, Glasgow.

I at once instructed an inspector of the Department to make inquiries into the facts, and in the afternoon he reported that he had traced three cases of death after short illness, one on 1st March, and two on the 6th, all being females employed in this hair factory. The bodies of two had been already interred. That of the third I saw about 4 p.m. of the same day, and in order to secure a post-mortem examination and full investigation I reported the death to the police. Next day I also made a personal statement to the Procurator-Fiscal for the county of Lanark. He ordered a post-mortem examination, which was made by Dr. Samuel J. Moore, one of the Medico-legal examiners for the Sheriff of Lanarkshire, on the afternoon of the 8th. The following statement of the symptoms, &c. in those and in other cases of illness subsequently discovered is compiled from notes made by myself at the residences of the parties, and comprises also all the information which could be obtained from every available source, as to circumstances bearing upon the cases.

1. A. M. L., aged 16, hair-spinner, residing at 32, Silverfir Street, came home from her work at the dinner hour (2 p.m.), 26th February, feeling very ill. She was seized just before leaving off. She said, "I am very bad. My head and my heart!" and laid her hand over her stomach. Vomited everything and constantly called for water. Did not sleep during the first night. Bowels moved twice on 26th, and motions were natural. Continued very restless throughout, constantly covered with a cold sweat, and could not be kept in heat. No convulsions. Became "Blue like Magenta" before her death on 1st March. Was seen by Dr. Menzies about an hour *after* death. Red blood oozed from the nose and mouth soon after death, but no blood was observed in stools or expectoration during life. No broken skin or local swelling was observed by those who laid out the body. The death was registered as from an "unknown" cause, and the body was interred on the 5th March.

2. M. McC., aged 32, "yard-woman" in hair factory, residing at 63, Nicholson Street. Usually employed hanging up the hair-ropes in the stove after steaming, but had fed a hair-carding machine for a few days before her dismission on 4th March for misconduct (drinking). Came home at breakfast hour saying she was not to get back to her work. About 5 p.m. went to bed, complaining of "lightness in the head" and pains in her chest and stomach. Had cold sweating that night.

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* See also Dr. Ballard's Report on this manufacture, p. 43.

Throughout was very cold. Did not vomit but had great thirst and drank water copiously. Was always very restless, so that could scarcely be kept in bed. Skin became blue, and her whole aspect at the close of her life reminded her mother of people she had seen dying of cholera. Her bowels were moved by medicine. Never passed blood by stool or expectorated blood. Had often been observed to cough and spit up black stuff after coming from her work. Died 6th March at 8.30 a.m. Body seen by Dr. Barrie four hours *after* death. Blood began to ooze from nose and mouth very soon after death. The death was registered "sudden, supposed heart disease," and the interment took place on the 7th. No broken skin or local swelling was observed by those who laid out the body.

3. A. N., aged 26, "yard-woman" in hair factory, residing at 46, Rose Street, S. Employed in carrying hair-ropes from the spinning room to the steam-chest in yard. Came home at the breakfast hour on 4th March, saying she was very bad, pained all over, but especially in the head, back, and stomach. Slept well that night, but became very restless next day, vomiting frequently, and being very thirsty. On the morning of the 6th was greatly exhausted, still vomiting, but no diarrhœa, no blood in stools or expectoration. No convulsions or cramps. Was first seen by Dr. Mullan about 15 minutes before death, which took place at 3 p.m. on the 6th March. The body was seen by me at 4 p.m. on the 7th, when blood was oozing from nose and mouth so as to soak a towel and the pillow and bed-clothes. A post-mortem examination was made at 3 p.m. on the 8th, under warrant from the sheriff, by Dr. S. J. Moore and myself. No broken skin or local tumour was discovered. The body was enormously swollen from advanced putrefaction. A report was duly made to the Fiscal by Dr. Moore, but owing to the state of the body the pathological appearances were entirely destroyed. In our opinion they pointed to some form of blood-poisoning as the cause of death.

Contemporaneously with those three fatal cases of illness there were four girls attacked with symptoms apparently the same in kind, although much milder in degree, and all ending in recovery, viz. :—

1. C. D., aged 24, hair-spinning machinist, residing at 37, Dale Street. Took ill on 1st March with severe pain and "lightness" in the head, also pain in stomach, right side of abdomen, and chest. Felt nausea, but vomited little. Had quite recovered, excepting a sense of weakness, on 9th.

2. M. H., aged 24, hair-spinning machinist, residing at 5, King Street, City. Seized with exactly the same symptoms on 1st March. Was seen by me on the 7th, when she was suffering from debility but recovering.

3. H. C., hair-spinning machinist, residing at 27, New Wynd. Seized at the same date, with the same symptoms. Seen by me on the 7th sitting up, and recovering, but weak.

4. B. R., aged 19, hair-spinning machinist, residing at 42, Thistle Street. Seized on 7th March with the same symptoms. Was seen by me at 4 p.m. on that day, when pulse was 96, and temp. 99° F. Still nauseated. Vomiting throughout more urgent than in other cases. Was able to rise next day, and recovered.

Another contemporary case of illness is worthy of special notice from the presence of a local lesion, which was absent in all the other cases, viz. :—

5. S. F., aged 20, hair-carding machinist, residing at 41, Charles Street, N. On the evening of 1st March returned from work feeling ill, and was unable to turn out next morning. Observed a pimple on outer aspect of left upper arm. Not aware of having pricked herself

or being otherwise injured there. On Monday 4th March went to work, but had to return home. On the 5th Dr. Walker saw her. Had headache, and arm was slightly swollen. Seen by me at 6 p.m. on the 7th. Her pulse was 120, the axillary temp. 101° F. The tongue was coated with thin yellowish fur. Complained only of pain in left upper arm, the outer aspect of which was much swollen, the tissues brawny, and the skin tense and red. At seat of pimple there was seen a *black* spot, as large as a threepenny piece. Arm being poulticed.

On the 8th at 11 a.m. her pulse was 96, and the temp. 99° F. A crop of miliary pustules had appeared over the inflamed area surrounding the black spot, which was larger. Swelling more diffused round her arm, but pain was considerably less. On the 9th, I found the girl up, and dressed, but looking very pale and faint. Her tongue was clean, the constitutional symptoms gone, and the local swelling less and the pain gone. She recovered gradually, the illness leaving great debility behind it.

On 1st April I received intimation of the death of another hand employed in the hair factory, but not in the hair department. The following is the history of the case :—

M. D., aged 20, fur-cutter in Adelphi Horsehair Factory, residing at 3, Saracen Lane. On 29th March was seized with slight shiverings and colicky pains in her bowels. Next day observed a swelling of left cheek. On the 31st this swelling had extended down over neck, and she consulted Dr. Meighan at his surgery 219, Gallowgate. He has drawn up for me a full report of the case, which, after reciting the facts already given, proceeds :—" Patient said she felt slightly giddy, but had " no distinct head-ache. The tongue was dry and furred, and brownish " in the centre, the pulse was full and bounding, 90 in the minute. " Skin of body generally was dry, but not hot to touch. The face " showed a circumscribed flush on each check. The swelling covered " chiefly the parotid region, extending downwards as far as the clavicle " and spine of the scapula, backwards over the side and back part of " the neck as far as the vertebral spine, and upwards by a narrow ridge " over the zygomatic arch on to the temple and forehead. The swollen " part had a firm brawny feel and pitted slightly on pressure. There " was but slight redness and no pain or tingling. I noticed also a " swelling about the size of a crown piece on the left side of the fore- " head. Its surface was glossy and had a livid hue, with a reddish " elevated spot in the centre, and on inquiry, the patient stated that " two or three days before, this had begun as a small pimple which " became itchy, and the head of which had been broken off by scratching. " She also stated most particularly that the appearance of this pimple " had preceded the other symptoms, both local and constitutional. This " swelling was firmer and more inflamed than the other swollen parts, " and she complained of throbbing pain in it. I cauterized the pimple " with acid nitrate of mercury, and prescribed carbolic acid internally. " At 8 p.m. I again saw the patient. She was sitting up in bed, very " restless and anxious. The swelling had increased considerably, and " had now extended to two inches below the clavicle and spine of " scapula on the left side, crossing to the right side of the neck in " front. Her cheeks were more deeply flushed. The whole of the " swollen part had now become of a deep red colour. The lividity on " the forehead was also more marked. Patient complained much of " thirst; she felt frequently inclined to vomit, and the bowels had been " purged two or three times during the evening. She had also colicky " pains in the bowels at intervals. Pulse 120, soft, and irregular. " Breathing was oppressed and laborious, and she complained of a

"choking sensation in her chest. There was marked foetor of the breath. "I did not see the patient again, as she died at 4 a.m. on next day "(1st April). I heard from her friends that she had vomited several "times and had frequent desire to empty the bowels. She soon how- "ever became very prostrate, and was comatose for some time before "death."

Dr. Meighan certified that the death of M. D. was caused by "malignant vesicle."

The case was reported to the Fiscal, and a post-mortem examination of the body was made under a sheriff's warrant on 2nd April in the mortuary of the Central Police station, 36 hours after death, by Dr. Moore, in presence of Dr. Foulis, lecturer on pathology in the Royal Infirmary Medical School, and myself. The following is an extract from Dr. Moore's official report:—

"The body was well developed and bore no mark of violence. Rigor-mortis was partially present. A little froth exuded from the mouth and nostrils. A small discoloured patch was observed on the forehead as if produced by nitrate of silver, in the centre of which there was a scab. There were a few very small petechial spots over the sternum and breast. There was a swelling on the left side of the neck, and over the left shoulder. Post-mortem hypostasis well marked over the back. The brown mark on the forehead on being incised appeared to be quite superficial. There was no œdema at the part. On cutting into the swelling on the neck, the tissues were very œdematous, and on incising the part deeply, some cheesy glands were observed. The tissues on the left shoulder and over the upper part of the chest were also very œdematous.

"*Chest.* The trachea contained some froth, but its lining membrane appeared normal. On removing the sternum the anterior mediastinum was found to be very œdematous. The right chambers of the heart and the large vessels leading thereto were filled with thin fluid blood of a dark red colour. The left chambers were contracted and empty. The lungs were bound to the parietes by old adhesions. At the lower and back parts they were much loaded with thin dark red blood which exuded freely from the cut surface. *Abdomen.* Some parts of the mesentery, and of the peritoneum were œdematous. The falciform ligament of the liver was very œdematous, and the serous fluid infiltrating it had a turbid, almost milky, appearance. There was a considerable quantity of straw-coloured serous fluid in the abdominal cavity. The stomach contained some partially digested food and some fluid. A few spots of extravasation were observed in the mucous membrane. The spleen was slightly enlarged and pulpy soft. The liver and kidneys seemed normal. Nothing further worthy of note was observed. The stomach and its contents were placed in a jar, sealed and labelled for further examination if considered necessary. Microscopic examination of some of the fluids was made as the dissection was conducted, and a portion of lung was retained for microscopic examination of the mucus in the air passages."

Dr. Foulis reports the results of his examinations:—"In the vicinity of the glands of the side of neck the cellular tissue was much swollen, and œdematous, and there was decided œdema in the anterior mediastinum down to the diaphragm. The fluid of those parts had a peculiar opalescent appearance, and on microscopic examination crowds of the *Bacillus Anthracis* were observed in a clear colourless fluid. Some of the blood from the œdematous regions of the neck was also examined and found to contain the same bacilli, though in less abundance. The same may be said of the blood from the heart. The red corpuscles did

not tend to arrange themselves in rouleaux. The bacillus rods were motionless, of a dimly transparent pale aspect, and of the length of two or more diameters of the red blood corpuscles. The mucus in the air passages contained the usual products of catarrh of the mucous membrane, a very few bacilli, and no dust or portions of hair."

The first question is—what was the nature of the disease which attacked those hair-workers? As I am chiefly concerned with the circumstances under which the disease arose, and its relations to this special trade, I shall state at once, and without discussion of the symptoms, appearances, &c.* that all these cases were in my opinion but various forms of the disease known as Anthrax, Charbon, Milzbrand, Splenic Fever, Malignant Pustule, &c. &c., which is primarily an affection of horses, horned cattle, and sheep, but which may be propagated among all warm blooded animals, including man. The contagium is demonstrated to be the *Bacillus Anthracis*, a fungoid organism which infects the blood and tissues, which in its full development assumes a rod-like form and is very perishable, but which propagates by spores which are very tenacious of life, and in fact are, when dried, practically imperishable. These organisms were actually observed in the blood of M. D., when examined microscopically. From the general and local symptoms, we have seen that Dr. Meighan certified her death to be from "malignant vesicle." I may also add that Dr. Hector C. Cameron, surgeon to the Royal Infirmary, had no hesitation in agreeing with me that the girl S. F. had "malignant pustule," the whole aspect of the case reminding him of a patient, a hair-worker in the same factory, who died in 1876 from that disease, in whose blood also the bacillus was detected by Dr. Foulis. The particulars of this case will be given subsequently.

The variety in the nature of the disease in these cases has an interesting and important bearing upon their causation, and may, therefore, be more particularly discussed.

Anthrax assumes different aspects, apparently depending on the mode

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* To aid in the intelligent consideration of these cases, I give from Hirt (24) and Bollinger (23) the following compendious account of the chief symptoms and post-mortem appearances of *internal* anthrax. The *external* carbuncular form is easily recognised and therefore need not be described :—

"Malignant anthrax œdema is distinguished from malignant pustule in this, that the vesicle and primary pustule are absent. There is no essential difference in their future course. The œdema, a pale yellow swelling, is observed at first only on the eyelids, but spreads later to other parts of the body. The intestinal mycosis arises from internal infection. Its symptoms have been carefully investigated only recently. The initial stage of this affection is scarcely to be distinguished from that of other acute diseases. Depression, faintness, headache, giddiness, and gastric disturbance ensue, and a painless, sometimes bloody diarrhœa sets in with increasing force, leading very frequently to speedy collapse. The patient is often tormented with violent headache, and colicky pains in the abdomen; the respiration is painful and frequent, the pulse quick, and sometimes there are epileptiform convulsions, opisthotonus, and dilatation of the pupils. Local lesions on the skin in the form of small carbuncles, and upon the mucous membrane in the form of hœmorrhagic effusions may frequently be found. A fatal termination has ensued in almost all hitherto observed cases, generally between the first and seventh day after the outset of the illness." (Hirt, p. 104.)

The post-mortem appearances in internal anthrax are thus summarised by Bollinger :—"In the abdominal cavity there is generally a moderate serous or sero-hæmorrhagic effusion, and sub-peritoneal suggillations in moderate amount; the retro-peritoneal and mesenteric connective tissue is infiltrated, jelly-like and of a yellowish and reddish colour" (p. 419).

In all cases the detection of *Bacillus Anthracis* in the extravascular fluids and blood is decisive of the nature of the disease. Rapid decomposition, with its external phenomena—swelling, discolouration, sanguineous exudations from the mouth and nose, &c. are always observed.

of access obtained by the infecting organism to the system, *i.e.*, according as it is inhaled or swallowed, or enters locally by the hair-follicles or other natural or artificial openings in the skin. In the former case it is called charbon fever (*fievre charbonneuse*), intestinal or internal anthrax, and mycosis intestinalis, the symptoms being from the outset constitutional. To this category the cases of A. M. L., M. McC., and A. N. belong. In the latter case it is known as malignant pustule, charbon, or anthrax proper, the constitutional symptoms being preceded by, or at any rate advancing *pari passu* with certain characteristic local appearances of the nature of a carbuncle or pustule. To this class belongs the case of S. F.

The last fatal case, that of M. D., also belongs to this class, but to the most rapidly fatal form of local infection, or it may be to a combined local and constitutional infection, in which the specific contagium at once passes from its local nidus into the surrounding tissues, and thence permeates the whole body. This has been styled œdematous charbon (*C. Œdemateuse*), malignant œdema (*Œdeme Malin*), or malignant anthrax œdema (*Bösartige Anthrax Œdem*).

The general circumstances under which anthrax manifests itself in man are these: It is always observed in persons employed, either in the care of animals during life, in their slaughter, or in trades and manufactures connected with the utilisation of the various parts of animals. The localities in which outbreaks have been observed in man are therefore either anthrax districts, *i.e.*, districts where anthrax is prevalent among animals, or places at a distance where it is unknown as an epizootic, but to which, in the course of commerce, the products of infected animals may be conveyed. As every single item of these products may be a carrier of infection, the ultimate place of manifestation of the disease is as varied and widely distributed from the original focus as the products and their destination. Hair, wool, bristles, hides, horns, hoofs, &c. being valuable articles of commerce and in wide request, those parts of animals have furnished the most startling demonstrations of the vitality and portability of the disease by its propagation to man. Hirt (24) thus enumerates the various classes of workpeople who have suffered:—"Tanners, makers of coarse hats, fell-"mongers, furriers, fur dyers, workers in horsehair, wool, and paper "factories, and ropemakers who clean hair brought from abroad, *e.g.*, "from Russia" (p. 102). This reference to the special likelihood of Russian hair conveying the infection shows that anthrax may so constantly be present in certain countries as to mark out the spoils of their animals as specially likely to contain and convey the disease. We are told by several writers that there is no country where anthrax is more constantly present and severe in its ravages among horses and horned animals than in Russia, especially in Siberia. In Siberia horses are the chief victims. Naturally cases in man are also very frequent there, resulting in epizootic years in hundreds of deaths. This sufficiently accounts for the circumstance that "Russian hair" is very frequently mentioned in records of outbreaks of anthrax among hairworkers; and hair is more frequently associated with such outbreaks than any other animal product.

A few references will prove how thoroughly recognised by continental writers were those risks of the hair trade. The first also shows how very early Russian hair gained an unfortunate notoriety in this relation.

Heusinger (8) quotes from the "Memoires de l'Académie de Med." so far back as 1777 the following passage:—"Malignant carbuncle in "Paris as a rule only affects those engaged in two trades, the tallow-

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" chandlers, or those who work with mutton fat, and horsehair workers. " The latter are most frequently affected; indeed it is seldom that they " pursue this trade long without suffering from it, and many die. They " have observed that the hair whose manufacture is most dangerous is " that which is imported from Russia. This hair is usually in a bad " condition ; a part is sometimes transformed into grey dust, and has a " disagreeable smell. The case of carbuncle which Paulet saw was " that of a young woman who had opened a bale of this hair " (p. 403). In 1822 Patissier published a book (1) based upon Ramazzini's historic treatise "De Morbis Artificium," (Padua 1713), a section of which is entitled "Maladies des Criniers." He there states :—" Workmen who " unpack bales of hair and who beat them are liable to contract malig- " nant charbon and boils. The 'Gazette de Santé' (March 1777) " contains the history of some workmen who had been attacked with " those diseases after having without sufficient precaution opened and " sorted bales of hair imported from Russia" (p. 242). In 1860 Vernois, in his "Traité pratique d'Hygiène industrielle," (12) has an article " Crins (Preparation des), Appret et teinture " from which we learn that this trade was by the French Government in 1843 placed in the third class of dangerous employments as requiring police supervision. Among the "causes d' incommodité" he mentions :—" Dust in the " beating and sorting rooms. Sometimes the occurrence of serious " mishaps to the workers, through the hair being impregnated with " the blood of animals dying of charbon or glanders." In Tardieu's " Dict. d'Hygiène" there is an article, "Criniers," in which those risks are mentioned as common, and certain precautions are recommended. Eulenberg (20) and Hirt (24) have similar references. This is enough to establish the statement that since the earliest systematic treatises on industrial hygiene, the dangers of the manufacture of hair as a medium for the conveyance of animal poisons to man have been recognised and amply discussed by foreign authors.

The fact that anthrax is enzootic in the pastoral districts of all the chief European countries excepting Great Britain, sufficiently accounts for the circumstance that all our precise knowledge of the disease, both in the lower animals and in man, is derived from the observations and investigations of foreign writers. It is, nevertheless, remarkable, considering our commercial relations with those countries, and the existence among us of old established and extensive hair factories, that so far as I can discover only one casual record has been made of malignant pustule in connexion with an English hair factory.

Indeed in Thackrah's (4) small treatise on trade diseases, published in 1831, the first work in the English language devoted to the systematic treatment of this department of hygiene, we find this passage, which proves that it was not want of knowledge or observation of the hair trade in its health aspect which caused the communication of specific infection to be overlooked :—" Preparers or dressers of hair— " men, women, and boys—are in an atmosphere of dust and stench, " especially when employed on the foreign article. The winnowers suffer " most. The complexion is soon rendered pale, the appetite reduced, the " head affected with pain, respiration impeded, cough and expectoration " established, the body emaciated. I scarcely need add that life is " sacrificed to a continuance of the employ. In most baneful arts " and occupations the wages are high, but here we find with surprise " that a winnower does not earn more than 4*s.* 6*d.* or 5*s.* a week. " For what a pittance is health broken and life destroyed! But why " should the winnowing be effected by hand at all? Why not employ " machinery to turn the fan? Or why not collect the dust in a box

" and carry it off through a wooden chimney by the current from " the fan? Few persons indeed are employed in the dressing of hair, " and fewer are acquainted with their situation and suffering. This " may palliate, but cannot excuse the neglect" (p. 69). Therefore "foreign" hair was then imported into England, but was known only as more productive of "dust and stench" than the home article. That specific infection was not observed even more recently becomes the more remarkable when we remember that Dr. William Budd read a paper before the British Medical Association in London in 1862, entitled, "Observations on the Occurrence of Malignant Pustule in England, illustrated by numerous fatal cases" (published in "British Medical Journal" for 1863). At that date he could not refer to a single case in association with a hair factory in this country (evidently not being aware of Mr. Lawrence's cases, which were published in 1847), but he quotes two continental examples. Yet with these suggestive incidents, so widely published, no similar mishap seems to have attracted attention in this country during the intervening 16 years. Additional facts made out in reference to the Glasgow Hair Factory, discovered and interpreted in the reflected light of the events above recorded, make it unfortunately too probable that we cannot infer from the absence of any record of such outbreaks of anthrax among British hair workers that no such outbreaks have occurred. The probability is that they have occurred from time to time, but being chiefly of the intestinal or internal variety, as in the present instance, they have not been recognised.

I have not been able to obtain full details of all the hair outbreaks recorded, but it will be useful to collect such facts as I have alongside of the Glasgow cases, before considering the circumstances special to this trade, which originate and facilitate those accidents, preparatory to suggesting preventive measures.

Rayer (3), states:—" During the three years I was attached to the " Hospital St. Antoine, I saw several cases which all came from the " same manufactory, in which the business of cleansing and preparing " hair, imported from Russia, was carried on" (p. 558). Budd refers to this statement and says that these cases were eight in number, and calls them "malignant pustule," but Willis' translation of the second edition (1835), to which alone, and to the original first edition (which contains no mention of the facts), I have had access, specifies no number.* In the translation one hair factory case is detailed, and three casually mentioned, all of date 1829, on the statement of one of those patients. Two are undoubted illustrations of the true external anthrax, the local tumor being on the face and neck in one and on the thigh in the second. All were fatal except this last. Rayer, says: "According to the " patient, weakness, prostration, and spitting of blood are symptoms of " frequent occurrence among the workers in hair. His daughter had " died after an illness of five days, with symptoms of this description, " and one of his fellow labourers had sunk, some time previously, in two " days" (p. 567). This rapidly fatal case is certainly suggestive of the internal form of the disease. Another fatal case of external facial anthrax is detailed, which occurred in a female "carder of mattresses." Proust (19), also refers to the liability of "mattress-workers" to charbon. Budd says, "I think it is the same writer (Rayer), who " records the still more remarkable case of three persons who were " attacked with the disease after cleaning some hair that had for many

* There was a new edition of Rayer published in 1845, to which Budd no doubt refers, but which I have not seen.

" years served as the stuffing of an easy chair." I have not been able to verify that reference to Rayer, but such an occurrence is quite within the range of possibility. Given the contagium in a dry condition, and it seems to have no limit to its potential vitality.

There is a valuable special paper on the association of hair manufacture with charbon, by Dr. Ibrelisle (5), published in the "Annales d'Hygiène" (1845) :— "Sur les Accidents qui peuvent resulter de la Manipulation des Crins." It is introduced by the following remarks on the general question by the editors:—"Experience has super-" abundantly proved that animal matters long accumulated yield a dust " which is extremely injurious to persons who breathe it. This is " especially true of hair. This material, charged with cutaneous " secretions and blood, befouled by fœcal matters which escape at the " moment of slaughter or of natural death, is packed in bales to be " exported from Brazil, Buenos Ayres, or Russia. It yields a dust from " animal debris, fermented and changed in character, which will " certainly prove poisonous if inhaled in great quantity. It is not " necessary for the explanation of this poisonous property, to assume " that the animals have died of contagious diseases." (p. 339).

The editors of the "Annales d'Hygiène" doubt the specificity of the effects of foul hair ; and certainly Dr. Ibrelisle's cases of malignant anthrax are peculiar in this, that they were distinctly associated with other cases of boils or simple furuncle. They occurred among the male prisoners in the prison of Metz, and only among those who were employed in beating, picking, and teazing hair. In May 1842, four were seized with boils, appearing in numbers on the back, the neck, the arms, and the thighs in each case; preceded by debility and gastric disturbance. These were followed by a fifth case having all the characteristics of "true charbon" on the right neck. In succession there were six similar cases, the anthrax pustule being on the neck in four, on the cheek in one, and on the loins in another. Besides these characteristic cases there were five of an intermediate character, the local lesion being on the shoulders, neck, and thigh, and lastly, eleven cases of simple boils like the first four. Dr. Ibrelisle says that the employment was very dusty, and that the foreign hair produced a risk not only from the dust, but from contagious diseases; but he adds, "I " attribute to a common cause the eczematous eruptions which I have " observed, from 'le furuncle simple' to 'l'anthrax grave'".* He bears distinct testimony to the fact that these risks were well known to attend all hair manufacture. "Medical men who have studied the " diseases of artizans, regard work among hair as very dangerous to " those who engage in it." One-third of all the prisoners engaged in this work were attacked, an excessive proportion, which he attributes to the small ill-ventilated cells in which it was carried on.

Trousseau's cases are quoted frequently (7). He states (Gaz. Med., January, 1847) that in two Parisian factories for working up horsehair from Buenos Ayres, and in which only six or eight hands were employed, 20 persons died in the course of 10 years from malignant pustule. He himself treated three cases from the same factories, successfully by means of severe cauterization.

In the Second Annual Report of the State Board of Health of Massachusetts, U.S.A., for 1871 (19) there is a paper giving a very complete account of 26 cases which occurred between 1853 and 1870 among the

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* These facts and opinions, especially the facts, are very interesting in view of the theory of the late Dr. Laycock that ordinary carbuncle arises from the imported poison of "epizootic carbuncle." See paper on "Contagious Furunculoid."— "Edinburgh Medical Journal," June 1857, Part I.

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workers in a hair factory in the town of Walpole in that State. This paper is all the more valuable to us that it views the subject from a preventive aspect.*

The whole history is so analogous to what we shall subsequently see has been the history of the disease in the Glasgow Factory that I must give it in some detail. The first case occurred in 1853. A workman was taken suddenly ill and died in two days, a well marked characteristic vesicle having in the meanwhile appeared. The next case occurred in April 1861, when "another man expired after an illness of 24 hours, having " obscure symptoms of blood-poisoning, but without the appearance of any " vesicle. Two months later this was followed by another case, accom-" panied by a vesicle upon the neck." *These isolated cases attracted little attention at the time.* "In March 1866 another operative died, " manifesting unmistakable symptoms of charbon, and from that time " till July 1869 the disease seems to have lurked about this same fac-" tory, indicating its presence at pretty regular intervals. During this " period seven or eight cases have occurred each year, the average " number of operatives employed being about eighty." The following table shows the total number of cases up to November 1870, their nature and results :—

	Cases.		Died.
Malignant vesicle - - -	15	—	5
Internal lesions - - -	10	—	8
Malignant Œdema - - -	1	—	1
Total - - -	26	—	14

In the 15 cases of malignant vesicle the external lesion was situated in six cases on the neck, in five on the face, in one each upon the shoulder, nose, scalp, and arm. Of the eight fatal cases of internal anthrax five succumbed within 24 hours of the attack. Of the 26 cases, 24 were employed in manufacturing curled hair. Of the other two, "one was *a carpenter, who a short time previous to his attack had " worked about the buildings connected with the factory*, and the other " was seized shortly after having nursed her husband who had been ill " with the same malady." As to the source of the hair which introduced the poison we are informed that it was "sheared from the necks " and tails of living wild horses, and is imported in bales for the most " part from Buenos Ayres, *a small portion only being brought from " Europe.*" This latter statement suggests the question whether the "small portion" was of Russian origin, but no further information is given. The process of manufacture was much the same as that pursued in the Glasgow Factory (of which an account will subsequently be given.) "During all these processes the hands of the operatives are brought " constantly in contact with the hair, while in the vicinity of the pick-" ing machine the air is loaded with minute particles of dried animal " matter, so that there is every facility for absorbing the poison by both " contact and inhalation." It is noted that some specimens of the hair were quite clean, while others were "often matted together with dirt " and putrid animal matter." Repeated inoculation experiments were made upon rabbits with this animal matter, but "without producing any " characteristic effects." † In other American towns there are larger fac-

* See also Dr. Stone's paper (16) for fuller medical details.

† Virchow (10) made similar experiments on dogs and guinea-pigs with the same unsuccessful results (p. 387).

tories than that in Walpole, supplied with hair from the same sources, and "the most careful inquiry has failed to discover a single instance of "the disease, or anything resembling it in any other factory." The importers asserted that no similar accident had ever come to their knowledge. The bacillus anthracis was discovered by Drs. Stone (16) and Hodges (17) in two of the cases, one of external pustule, which, though very severe, ended in recovery, and one of the internal variety, which ended fatally.

In Mr. South's additional notes and observations, in his translation of Chelius's "System of Surgery," (6) published in 1847, I find the only record of cases of malignant pustule arising in an English hair factory. Three cases were communicated by Mr. Lawrence, who says, "In the "other instances, both of which were persons employed in a horse-hair "manufactory, the skin had sloughed before they came to the hospital. "The affected portions were circular, the size of a shilling in one, on "the front of the chest, that of a sixpence in the other, on the forearm. "There were no other local symptoms nor the slightest constitutional "disturbance." (Vol. I., p. 69.)

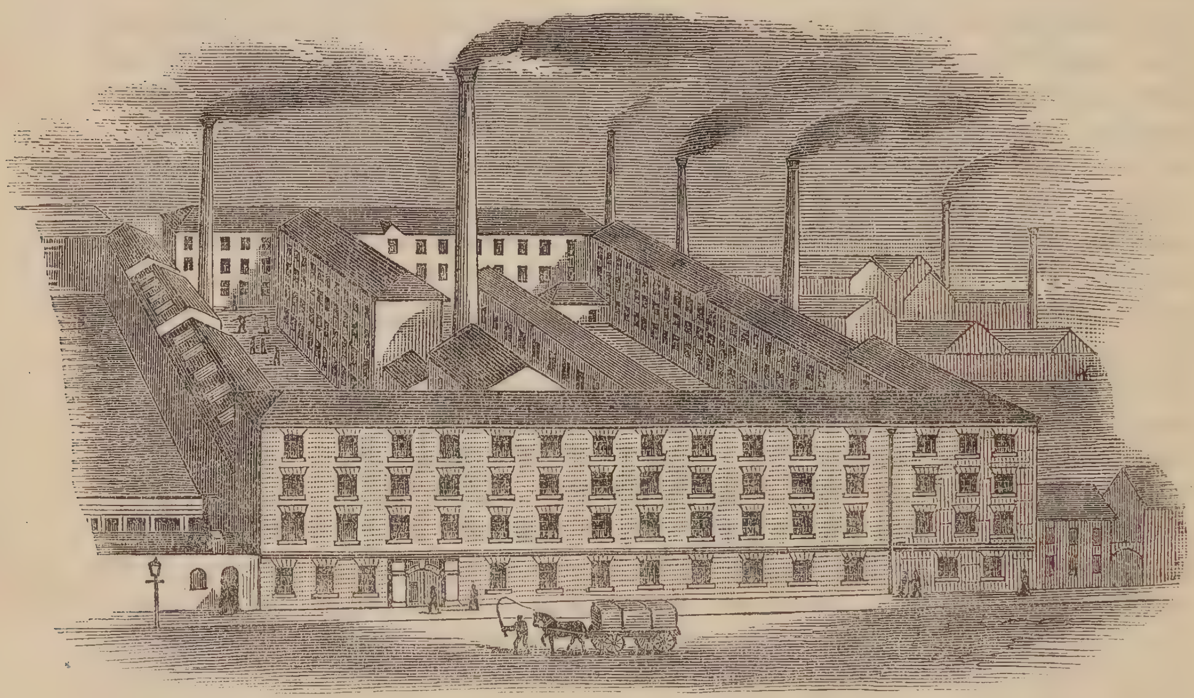
In a paper by Wagner (22) "Die intestinal Mycose und ihre Beziehung zum Milzbrand," there is a history of a series of cases observed in Leipzig with ample details of symptoms, pathological appearances, and microscopic examinations of the tissues and fluids. We shall confine ourselves to the facts bearing upon their ætiology. (1.) A dyer of sable furs died in hospital two hours after admission, 25th November 1872, his illness lasting about 24 hours, ending in epileptic convulsions, opisthotonos, and coma. (2.) A hair rope spinner, aged 23, who had been engaged in the manufacture of Russian horse-hair, walked into hospital 31st March 1873, complaining of diarrhœa, cramps confined to his left side, and colicky pains, his illness having begun 24 hours previously. He went to bed, and died almost immediately. (3.) A clerk, aged 30, entered hospital 26th June 1873, and died in 12 hours. Awoke feeling ill on 21st but worked till 24th. He was employed in the goods department of a railway. (4.) A message-boy, aged 16, employed in a factory where Russian horse-hair was in hands; observed a vesicle at left angle of lower jaw on 30th August, and entered the hospital on 1st September collapsed and cyanotic. He died on the 3rd. These cases furnish the basis of the paper, but the following are collected and added :—(5.) A hair rope spinner, aged 18, employed in the same work as (1) who had been carding Russian horse-hair which was intermixed with ox-hair, died a week after observing a vesicle under his chin, 20th February 1870. (6.) This case led to the discovery that "a workman "in the same work had two months previously become suddenly ill, "and died quite unexpectedly. A homeopathic practitioner regarded "the case as pneumonia, although he thought it obscure, and could "not account for the death." (p. 29.) (7.) A hair rope spinner, aged 21, died 6th July 1857 with symptoms of peritonitis after an obscure illness of about a week. (8.) A bristle binder, aged 60, died 27th March 1875 after a rapid illness of 24 hours, in which headache and vomitting were prominent symptoms. In cases 1, 2, 3, 4, 5, and 8, the *bacillus anthracis* was found in abundance, especially in the extravascular fluids, but also in the blood occasionally. Cases 6 and 7 are associated by Wagner with the others in the light of their ascertained nature, as being the same disease, but not recognised at the time. He also gives references to similar cases, not however in hair-workers, and quotes Neyding of Moscow, as saying that malignant pustule was observed by him most frequently in workers in hair and bristle factories. Münch also had examined in Moscow, within four years, no fewer than 28 bodies of persons who had died of this disease. In 15 there was

external carbuncle, in two it was very small and insignificant, and in 11 there was no external lesion whatever. These cases mostly originated in works where horsehair, and similar products were manufactured.

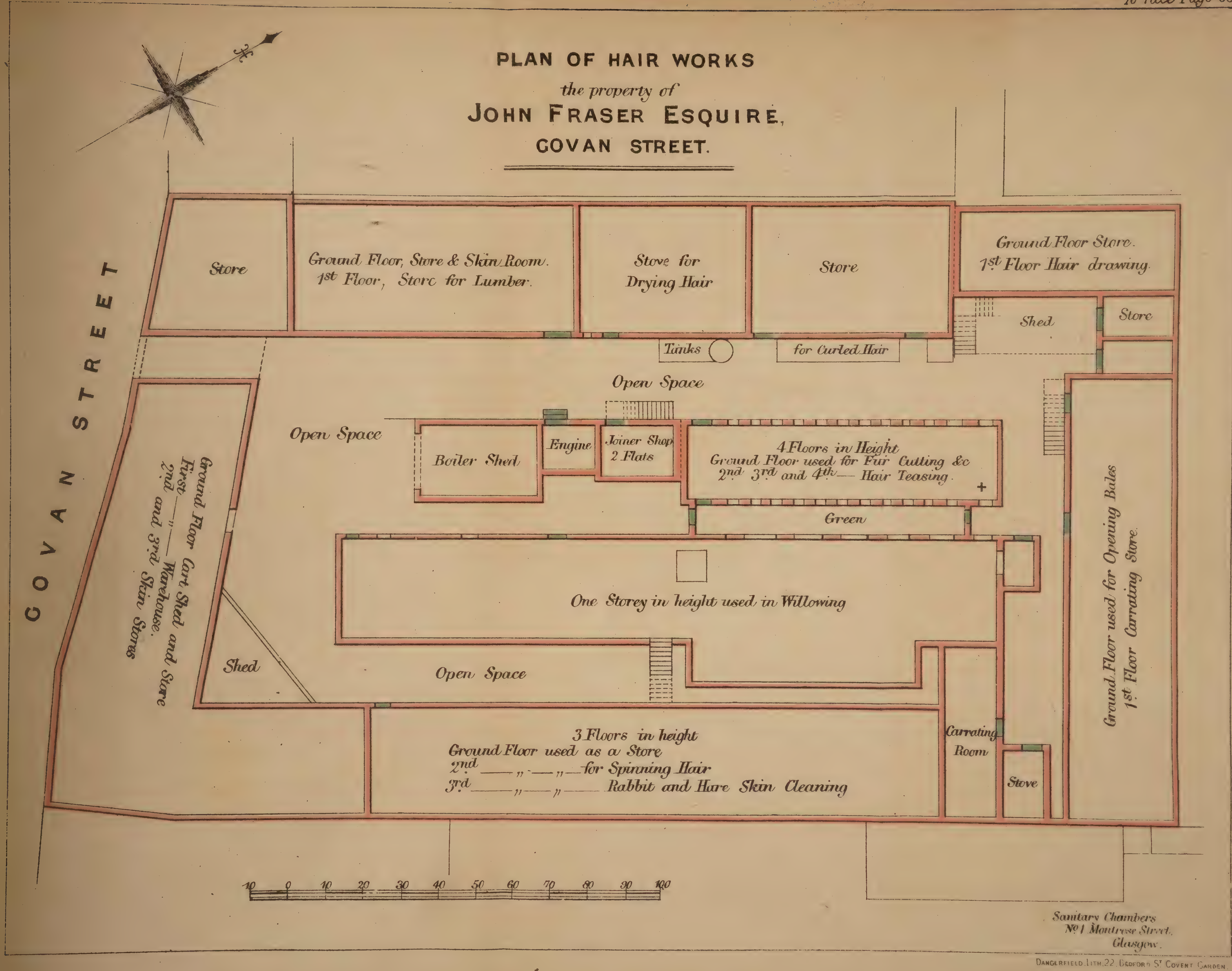
Wagner adds that such cases were unknown in Leipzig, in works where Russian or Siberian horse-hair was not manufactured, and that workpeople employed in the same works which supplied the fatal cases of internal anthrax had been treated for external anthrax in the surgical department of the hospital. He states that this hair was extremely dirty, and thinks that the bacteria get access to the stomach with food, especially with breakfast and afternoon refreshments, which are taken during work in the workroom, the viands being powdered with infected dust, or contaminated by the unwashed hands of the workers.

We see, therefore, that in Great Britain, France, Germany, and America, Russian hair has proved itself to be *par excellence* a dangerous material—the most dangerous hair in use; while not unnaturally in Russia itself the occurrence of anthrax infection in hair factories may be said to be frequent and deadly.

The Adelphi Hair Factory buildings are very extensive, as may be seen from the accompanying plan and this bird's-eye view. The particular part of the trade allotted to each building is marked upon the plan, so



that it can be readily made out where the processes to be described are carried on. It is not my intention to describe all the processes of all parts of the manufacture of the different sorts of hair, but principally to give an idea of those applied to the hair in question. The hair is received in bales, and is treated differently according to quality and destination. Some is first of all passed bit by bit through the hands of women, who with considerable nicety of touch teaze out and assort the various colours and qualities, removing in the process the grosser impurities. This is mostly done in the basement flats on the extreme left, and at the end of the enclosure opposite the main entrance. Some hair, such as that which caused this outbreak, is not sorted but is first unpacked from the bale to be subjected to the process of "willowing," in machines which by violent rotation and disturbance remove all dust and animal debris. It next passes on to the "carding machines," which


PLAN OF HAIR WORKS
the property of
JOHN FRASER ESQUIRE,
COVAN STREET.
GOVAN STREET
Store
Ground Floor, Store & Skin Room.
1st Floor, Store for Lumber.
Stove for Drying Hair
Store
Ground Floor Store.
1st Floor Hair drawing.
Shed
Store
Tanks
for Curled Hair
Open Space
Open Space
Boiler Shed
Engine
Joiner Shop 2 Flats
4 Floors in Height
Ground Floor used for Fur Cutting &c
2nd 3rd and 4th — Hair Teasing.
Green
Ground Floor Cart Shed and Store
First — " — Warehouse.
2nd and 3rd Skin Stores
One Storey in height used in Willowing
Ground Floor used for Opening Bales
1st Floor Carrating Store.
Shed
Open Space
3 Floors in height
Ground Floor used as a Store
2nd — " — " — for Spinning Hair
3rd — " — " — Rabbit and Hare Skin Cleaning
Carrating Room
Stove
10 0 10 20 30 40 50 60 70 80 90 100
Sanitary Chambers
No 1 Montrose Street.
Glasgow.
DANGERFIELD LITH. 22 BEDFORD ST COVENT GARDEN

remove all the finer dust, and improve the gloss and elasticity of the material. These machines are ranged in a long shed open to the roof, and are constantly surrounded with an atmosphere of dust. Their whole work is effected by rapid movement and disturbance of a parched unadhesive material, charged with dry debris, which it immediately sends off in the form of dust. It is not, therefore, in the nature of things possible that the work of feeding and tending these machines can be prosecuted without filling the lungs, and powdering the exposed skin and garments of the workers with this dust. The hair is now ready for the spinning and curling machines. For this purpose it is conveyed up a broad open stair, from one end of the machine-shed to the second flat of the building on the extreme right, which is open from end to end, and from side to side, and is lofty, airy, and well-lighted and ventilated with numerous windows. The operation of spinning closely resembles that of ordinary rope making. The girls carry the loose hair in bags tied round their waist, retreating backwards, applying successive portions of hair therefrom to the revolving rope, so that any remanent dust or microscopic particles are thrown up just about the breathing level. The tightly twisted and coiled ropes are now carried down the stair *through the carding shed* to large steam chests in the yard, standing in the open air at the foot of the chimney stalk on the left, where they are boiled and steamed for 20 or 30 minutes. On being removed from these vats the ropes are hung up in stoveing chambers on the basement flat of the building on the extreme left to be dried. The object of this is to "set the curl" and give the necessary elasticity to the manufactured article.

The special hair which was in hand at the time of the recent outbreak of anthrax is known as "Raw Russian manes," and being required of its natural mixed colour in the manufactured state was not assorted, but passed at once into the "willowing" and "carding" machines. The "Russian manes" were on this occasion put in hand on 16th February and withdrawn upon 2nd March, when the news of the death of M. L. on 1st March came to the ears of the proprietors. The relation of the illness of the workers attacked to these dates, and the nature of their employment, &c., will be seen at a glance from the following tabular statement :—

Name of Worker.	Nature of Work.	Date of Sickening.	Date of Death.	Duration of Illness.	Form of Disease.
A. M. L. -	Hair spinner	26th Feb. 2 p.m.	1st March -	3 days	Internal A.
M. McC. -	Yard woman	4th March 5 p.m.	6th do. 8.30 a.m.	39½ hours	Do.
A. N. -	Do.	4th do. 9 a.m.	6th do. 3 p.m. -	54 hours	Do.
S. F. -	Hair carding	1st do. -	- - -	Recovered	External A.
C. D. -	Hair spinner	1st do. -	- - -	Do.	Internal A.
M. H. -	Do.	1st do. -	- - -	Do.	Do.
H. C. -	Do.	1st do. -	- - -	Do.	Do.
B. R. -	Do.	7th do. -	- - -	Do.	Do.
M. D. -	Fur cutter	29th do. -	1st April, 4 a.m.	3 days	Mal. Œdema.

The "yard women" were employed in the steaming of the hair ropes. A. N. took the ropes from the spinning flat and put them in the steam chest, necessarily passing through the carding flat in the transit. M. Mc. C. hung up the ropes in the drying stove after boiling ; but it will be remembered that for three or four days before her dismission,

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she had fed one of the carding-machines. With these explanations a consideration of the nine cases of sickness yields the following results: Five cases sickened within the "Russian manes" period; two in two days thereafter, one in six days, and one in 27 days thereafter. Classified as to their departments, five were engaged in hair spinning, and one went into the hair spinning flat to remove the ropes; two were engaged in hair carding or "willowing," and one was employed in a distinct department of the business, fur-cutting, *i.e.*, tending a machine which shaved the fur off rabbit skins for the felt hat trade. As to the form of disease, there were seven cases of internal anthrax, of whom six were hair-spinners and one removed the ropes from the spinning flat; and two cases of external anthrax, of whom one was a carder, the other a fur-cutter.

Now, assuming the Russian "manes" to have been the source of the contagion, there are two facts which demand explanation: (1.) The sickening of four of these workers after this hair had been withdrawn from manufacture. (2.) The seizure of the girl M. D. not merely 27 days after this withdrawal, but although she was employed in an entirely different department, and was not necessarily in direct contact with the hair at all. The questions involved in the former case refer to time, in the latter to place and time. What is the incubation period of anthrax and and what are the laws which govern its diffusion? Nor are these questions distinct, *i.e.*, there may be something in the physical condition and laws of diffusion of the contagium which makes the difficult question of incubation of comparatively little practical importance in certain circumstances. Such circumstances attended the Glasgow outbreak. The incubation period is said by Raimbert to be one to three days; by Bollinger to be sometimes very short, but usually to be three or four or at most five days, and by Virchow to be most usually a few days rarely longer than 11 to 12, but frequently only a few hours, or it may be entirely absent. We might, therefore, bring the actual date of infection of all those cases save one within the "Russian manes" period, since they sickened from two to five days from its cessation; but the exception goes quite beyond such a theory, viz., the fur-cutter who tended a machine for shaving the fur from rabbit skins. She stood when so employed at the corner in the basement flat marked with a × in the plan, immediately opposite a window, in the middle of which was a ventilating pane of glass. Both hares and rabbits have been known to contract charbon in districts where it prevails among cattle, apparently from feeding on the same pastures. Indeed, at the very time of this occurrence in Glasgow, there was an outbreak of this disease among cows at Dalkeith near Edinburgh, and I learn from Principal Williams of the New Veterinary College, Edinburgh, that hares were frequently found dead in the locality, and were ascertained to have died of charbon. Raimbert (14) states that rabbit skins have been known to communicate the infection to man (p. 146). In the present case any such effect would in all probability have manifested itself at a previous stage of the manufacture, viz., in the process of combing and cleaning to which the skins were subjected before reaching the fur-cutting departments; but I believe that it was not contagion proceeding from the fur, but from the "Russian manes" which originated the disease in M. D., as in the cases of the girls actually in contact with the hair.

This brings us to the general circumstances of the outbreak in relation to the well known characteristics of the contagium of this disease. Here, as in reference to the matter of diagnosis as based on the symptoms and pathological appearances, I shall not enter into a minute discussion of this contagium. It is so easily recognised and isolated

that the *bacillus anthracis* has been the subject of most precise observation and experiment which have not only yielded a minute acquaintance with its own habits, but have thrown a flood of side light upon the phenomena of infection in general. Combining the results of those laboratory experiments with the observations so abundantly made as to the etiology of charbon, as seen in veterinary practice as well as in man, it has been ascertained that in the dry state, the contagium has scarcely any natural limit to its vitality, and is invulnerable by any artificial dry application or process. Moisture and the supervention of decomposition in the medium where it resides seem to bring the only natural termination to its organised existence, and infecting powers. Once let the medium in which the resting spores of the bacillus exist be dried, while yet fresh, whether that medium be some part of the animal, as bones, hides, horns, blood, &c., or some external fomites, as excrement, hay, straw, rags, hair, wool, which do not contain the poison in their structure, but include it in their bulk, and those substances become a perennial source of infection in fitting circumstances. Bollinger (23) states, "the customary medium of communication for anthrax poison " is the air whether the carriers of that poison (*anthrax bacteria*) come " out of the soil or are derived from living animals. The digestive " track holds the second place" (p. 384). "Small and light they [the " spores] are wafted by the breeze and either directly breathed in by " the animal, or they fall upon the fluid or solid food, and with it enter " the body." (p. 393).

If now reference is made to the description of the manufacture in the course of which those cases of anthrax arose among the workers, this is what we find. Those "Russian manes" more or less are derived from infected animals, they are more or less loaded with dried fomites, excrement, fresh desiccated blood, &c. The whole object and result of the various processes of "willowing," carding, and spinning is violently to disturb, dislodge, and dispel in the shape of dust those infected matters. The result was to create an infected atmosphere which not only pervaded the machine room and the spinning flat, but at the time of this accident must have extended outside, as the arrangements were devised so as to throw the greater part of the debris into the open air through shafts connected with the machines, and discharging on the roof of the machine shed. Hence, as seen from the window of the spinning-flat, there was a constant stream of dust pouring out of the ventilators and the roof of the shed, and even the vacant ground intervening between the two buildings was powdered thickly with this dust, and seeds of various kinds were here and there germinating. There can be no doubt that the more deadly seeds of anthrax were present in this debris, and from their lightness more plentifully suspended in and conveyed by the currents of air. We may, therefore, conceive the poison as not only in the general atmosphere of the yard, but as settling down in quantity on convenient surfaces in corners here and there, ready by a chance puff of wind to be blown again into dust, and so inhaled or deposited upon the skin or about the dress of any unfortunate worker in any department of the work who chanced to be near.* Once admit those physical conditions to be correctly described, and everyone of the cases is brought within the scope of their action. All the workers attacked were either engaged directly in the dust-producing processes, or indirectly brought within

* It is worth noting that the month of March 1878 was unusually warm and dry. There were only 11 days on which rain fell, and the total amount was but 1·6 inches. The fur-cutter sickened on the 29th, and during the previous 17 days there had been only on two occasions a trifling shower.

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the sphere of their influence. The case of the fur-cutter is precisely analogous to that of the carpenter in the Walpole outbreak. "A short "time previous to his attack he had worked about the buildings con-"nected with the factory." Among Wagner's cases also we find a "message-boy" employed in a hair factory. Why these persons were infected and the many who had casually been exposed had not been infected is a question easily to be solved in perfect consistence with the general phenomena of all infection, which work themselves out in the presence of such controlling circumstances as the physical facts of the case create. The material germs of disease are unequally distributed in the medium which contains and conveys them, and the actual infection follows or not upon the sufficient or insufficient insemination of the individual exposed.

The type of disease communicated corresponds with the conditions under which the infection occurred. Of the nine Glasgow cases, seven were examples of internal anthrax. Of the 26 American cases 10 were internal. Wagner's cases are all internal. In Russian factories the majority are of this type. Hirt tells us:—"The fact has recently been "established that internal infection may occur either through the inhala-"tion of anthrax bacteria with the air, or by their introduction with "food. The disease developed in consequence of this infection is identical "with Milzbrand, and has been observed and described under the name "of Mycosis Intestinalis by Waldeyer in a slaughter-house forage-"master; by Neyding and Münch in workers in bristle factories; by "E. Wagner in a fur dyer, three ropemakers, and a bristle binder" (p. 103). In all these occupations the material is dry and dusty and the process tends to infect the air, but in none on such a large scale or so necessarily and inevitably as in the manufacture of hair. In it the nature of the trade processes co-operates with the characteristics of the contagium to produce the most favourable circumstances possible for internal infection.

This tendency to internal infection in hair works has an important relation to the fact that so little has hitherto been observed of such occurrences in this country. I have already expressed the belief that this does not prove that the experiences of the continent are exceptional, but rather that here they have passed unnoticed. "In intestinal anthrax, "which is much more rare, it is difficult to make a diagnosis from the "symptoms and appearances alone. In consideration, however, of the "rapid onset of the disease, its acute course, and violent manifestions "(diarrhœa, vomiting, cyanosis, convulsions, collapse), and the "business of the patient, an accurate diagnosis is possible." (Bollinger, p. 424).

The proprietors of the Adelphi Hair Factory stated that in an experience of over 40 years, during which Russian hair had been largely manufactured, no such outbreak had occurred, or any mishap to direct their attention to the risks so generally recognised on the continent, though utterly unknown to them. But the narrative of the present outbreak makes it abundantly clear how readily even it might have escaped notice, not to speak of sporadic cases at long intervals such as preceded a similar alarming succession of cases in the Walpole Factory. The death of A. M. L. was registered as from an "unknown" cause; that of M. M'C. as "sudden, supposed heart disease;" that of A. N. as "unknown." Yet now that the facts are before us there can be no doubt whatever, that all three died from internal anthrax. There is therefore ground for suspicion that fatal cases may from time to time have been recorded on similar erroneous or imperfect information. This suspicion assumes the form of a certainty or a strong probability in

reference to three deaths of workers in this same factory which took place in 1876–7. My attention was directed to them and other deaths in connexion with another factory, by the statements of the workers in Adelphi Factory as to such events, the recollection of which was naturally revived at this time. There could be no doubt that in their minds at any rate "Russian hair" was associated with anticipated risks. The first case to which I shall allude was one of malignant pustule admitted under the care of Dr. Hector C. Cameron, into the wards of the Glasgow Royal Infirmary, on 10th October 1876. The following history is compiled from copious notes made by Dr. Cameron at the time, and kindly communicated to me. I have not dwelt much on the local appearances, which are minutely described, as there could be no question of the diagnosis, which was confirmed by the detection of the bacillus anthracis in the blood.

C. H., aged 19, residing at 237, South Wellington Street, hair spinner. A pimple appeared on 6th October 1876, on left angle of lower lip. It was black in the centre with a yellow ring outside the black, like a "shilf-corn" or a flea-bite. She made no complaint until 8 p.m. on the 7th, having gone to work that day. She then felt "out of sorts," and took some laxative medicine. The lip swelled up in the words of her mother, "as fast as a loaf in an oven." She was out of bed on the 8th, but on the 9th, felt very weak and was very restless. On the 10th, about mid-day, she entered the hospital, pulse 120, and the local appearances entirely typical of malignant pustule. Passed a very restless night, constantly endeavouring to get out of bed. On the 11th, her pulse was 140, temp. 104°·4 F., her respirations rapid and laboured; much moaning and restlessness. A plentiful crop of small vesicles and pustules had appeared over trunk and limbs, interspersed with numerous minute hæmorrhagic spots, permanent on pressure. On the 12th the patient was evidently sinking, pulse 140, respirations 50 per minute, and temp. 103° F., in morning; passed everything in bed. The minute vesicles were more numerous. Died at 9.3 p.m., the temp. being 106° F., an hour before death. On that day a sample of urine removed by catheter was examined. It was very red and turbid with amorphous urates; reaction highly acid. A precipitate of albumen was obtained, amounting, after subsidence for 12 hours, to two-thirds or more of the bulk operated upon. Under the microscope, besides a little scaly epithelium and amorphous urates, numerous tube-casts were seen, mostly filled with dark granular matter, but partly hyaline. No distinct blood corpuscles were detected, but a faint blue reaction with the Guaiac test was obtained.

A post-mortem examination was made on 13th October, 12 hours after death, by Dr. Foulis, whose report is as follows:—

Brain, 45 ozs.; right lung, 1 lb. 6 ozs.; left lung, 11 ozs.; liver, 3 lbs. 9 ozs.; heart, 9 ozs.; spleen, 8 ozs.; kidneys, 12 ozs. Body, examined 12 hours after death, shows rigor-mortis established. The under lip and chin are much swollen, the lip dry, caked, and brown; the chin and lower parts of the cheeks show numerous small purple spots, in the centre of which there is a minute excoriation. The whole body is dotted with minute purple spots, so small as to require close inspection to discover them, and there is also an eruption of pustules the great majority of which are of similarly minute size, while a few are rather larger. One in particular on the inside of the right knee is of the size of an ordinary small-pox vesicle. Chest—both pleuræ are the seat of acute pleurisy, with copious layers of soft lymph. In some of the lymph there has evidently been effusion of blood from the small vessels. The left lung is everywhere of a dark-red colour, and in places a little fluid

(reddish) can be squeezed out from the cut surface; the whole tissues of this lung are non-crepitant, and though not devoid of flexibility, present a solid resistance. The right lung is also dark-red in colour, but sub-crepitant everywhere. There are in this lung several small solid masses of triangular shape, and mottled red section, which are mostly near the surface; the size is that of walnuts. Heart, normal; no peri- or endo-carditis. Liver, normal. Gall-bladder, normal. Kidneys, pale; the minute venous radicles on the surface injected. Capsule easily removed; here and there are small mottled red and white masses of size of split peas, of same character as those in lungs. Spleen is pulpy of light plum-colour. Stomach, normal. In the cellular tissue behind the gullet is a hæmorrhagic effusion; the minute lymphatics in the gullet are injected in small beaded lines. Intestines, normal; except near the ilio-caecal valve, where there are in the mucous membrane of the ileum, numerous minute round, clear, raised dots, like enlarged solitary glands. Pelvic-organs, normal. The lip on being cut into creaks under the knife, and the whole of the veins in the tissue of the lips and chin are full of pus. The jugular veins do not show pus, nor are the lymphatic glands of the neck much enlarged, though rather congested. Brain is quite normal.

The following history of the illness and death of the foreman of the spinning department, in which C. L. was employed, and which was contemporary with her sickness, must be read in the light of her case. It was taken down by an officer of the Sanitary Department from the lips of a woman with whom he was cohabiting, and is of course necessarily defective.

W. C., aged 22, residing at 173, Mathieson Street, foreman of hair-spinning department. On 2nd October 1876 complained of a severe pain in his left side. During two following days became worse, but was able to go about. Called at the surgery of the late Dr. Martin, who told him that his stomach was disordered. On the night of the 4th October was very restless, scarcely sleeping any. Sweated heavily and had constant thirst. Got a dose of salts which he vomited. On the 5th was much worse. Bowels moved by castor oil. About 2 p.m. was seen by Dr. William Forrest, who injected morphia into his left side. About 4 p.m. fell out of bed in a convulsion fit, the contortions of his face and limbs being violent. Had to be held in bed by men. Died at 2 a.m. on the 6th. Soon after death his face and neck became black and swollen, and a discharge of blood came from his nose and mouth. Cause of death was certified by Dr. Forrest "delirium tremens."

In answer to my inquiries Dr. Forrest wrote (22nd March 1878) :—
"I find from my note book that the man C. was seen by me twice on "5th October 1876. I ordered him a mixture such as I was in the "habit of giving in delirium tremens. My memory of the case, with-"out notes of any kind to refer to (excepting the record of the visits and "the medicine got), is necessarily vague, but so far as I can recall the "circumstances, the case presented itself to me as one most probably of "delirium tremens. I was told that the man had been drinking. The house "looked quite like the home of a drunkard, bare and wretched, and there "was nothing about the case to raise the suspicion of any other cause "of illness. I remember that the man was in a state of violent "delirium when I saw him on the second occasion, being held down in "bed by some of his neighbours, and I remember also that I gave him "a subcutaneous injection of morphia. On neither occasion was it possible "for me to get a satisfactory examination made. Neither my brother "nor I have seen any case of sickness of any kind so far as we are "aware amongst hair workers, with, of course, the above exception."

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It only remains to state that both these persons were engaged in the manufacture of Russian hair at the time of their seizure.

Another case of fatal illness occurred in 1877 among the workers in the same factory. The cause of death is thus registered: "Inflammation of Brain." Duration of illness, three days. No medical attendant. Russian hair was again the material in hand. The following is the statement made to one of my officers. In the absence of medical testimony no better information can be obtained. In this, as in other cases, I preferred accepting inquiries made by a layman, as all chance of leading questions was in this way avoided.

M. H., aged 15, hair-machine feeder, residing at 212, St. James Street, Kinning Park. Her mother, now residing at 154, Crookston Street, states that M. went to her work in her usual health on the morning of 29th May 1877. She returned about 12 noon, sick, complaining of a severe pain in her head, and shivering. She went to bed and had a dose of castor oil which acted on her bowels once. Vomited constantly, and was very thirsty, perpetually asking for cold water. On the 30th and 31st these symptoms continued with increasing restlessness. On 1st June had three "convulsion fits." There was a pimple upon her left cheek which gave her great pain. It was blue in the centre, with redness round about. She died on that day, no doctor having seen her. Soon after death her body swelled, especially about the head and neck, and became discoloured. Blood oozed from her nose and mouth, and the smell was extremely offensive.

In the course of my inquiries into these deaths I heard of three cases of illness rapidly fatal which had taken place among the workers in another hair factory in the eastern district of the city. The attendant circumstances had evidently impressed the minds of the other hands in the same work, and reached the ears of those employed in the Adelphi Factory. Similar difficulties impair the value of the following narrative of these cases, but the facts were obtained as before through one of the district sanitary inspectors, who was not even aware of the history of the Adelphi cases, and consequently could not put leading questions.

1. M. B., aged 35, wife of a labourer, residing at 5, East Union Street, employed as a teazer in McRae's hair factory. From the statements of her husband and of a neighbour woman who had attended her in her last illness, it was ascertained that on 26th December 1876 she complained of shivering and a severe pain in her side, with general soreness in her bones. She had previously been a strong healthy woman, but had not gone to work for a few days, though no record of complaint of illness can be discovered until the 26th. On the following day she stated she had been very sick, vomiting whatever she took. This sickness continued, the pain in her side getting more severe, accompanied by a dry hard cough and a feeling of great oppression. On 29th December she consented to sending for Dr. Young, of Parkhead, who said she had severe inflammation of the lungs, and ordered a linseed and mustard poultice and prescribed a mixture. He visited again next day, but the pain was much worse and never abated. She died early in the morning of 31st December. Both informants stated that very soon thereafter the face and neck became swollen and black, and blood oozed from nose and mouth. The cause of death was certified and registered "probable pneumonia." This history was read to Dr. Young, who stated that it was correct, and that he regarded the case as doubtful, being so sudden in its termination.

2. H. J. O., aged 47, widow of a hawker, residing at 28, East Union Street, employed as a hair-teazer in McRae's factory.

The following statement was obtained from two female fellow-workers. She had been in the work for 18 months.

About a week before her death she complained of a severe pain in her side, but did not leave her work until the 26th November, 1877. On that morning she began work as usual, but in half an hour had to return home feeling very sick but unable to vomit, and having smart diarrhœa. Next night about 8 she was seen by Dr. Roy, Gallowgate. He said she was a done woman, and had heavy inflammation. He ordered poultices and prescribed. This treatment gave her no relief. The sickness continued, with a gradually increasing sense of oppression and smothering. She died on 28th November. Swelling and discolouration of the face and throat soon set in.

The cause of death was registered, but not certified, "Chronic bronchitis and pleurisy." This statement was read to Dr. Roy, who said that it was correct so far as he knew, and that the woman appeared to be done with bronchitis.

3. E. S., aged 49, widow of a labourer, residing at 28, East Union Street, a hair-teazer in McRae's factory.

The following statement was obtained from the same fellow workers as in the preceding case. They had lodged with Mrs. S., who was apparently a very healthy woman, and had been employed about nine years in the same work. Heard no complaint whatever until between 4 and 5 on the morning of 4th February 1878. She then said she had had a shivering and been seized with severe pain in her left side, so that she had to get upon her hands and knees in bed in order to breathe easily. About mid-day she managed to rise and dress, and go to the railway station in Queen Street to inquire for a parcel which she expected. In the evening she got home and went to bed. Next day she took a dose of salts and cream of tartar which operated once. On the 6th Dr. John Miller, Gallowgate, saw her about 2 p.m. He said there was severe inflammation of the left lung, and ordered poultices and prescribed. She was very much nauseated, but could not vomit. She was unable to bear the poulticing. On the 7th, about 3 p.m., the doctor stopped the mixture and ordered a tablespoonful of whisky in water every two hours. She was unable to take it, and complained much of a sense of smothering. She died about 8 o'clock that night. The following morning the body was much swelled and discoloured, especially about the face and throat. The cause of death was certified and registered "Inflammation of left lung." This statement was read to Dr. Miller, who said it was correct; that he prescribed the whisky because the patient's face was pale and her lips blue, and said that now he was inclined to regard the case as one of blood-poisoning got from the hair.

I have seen the Messrs. McRae, in whose works these women were employed, and found them extremely anxious to give me the fullest information. "Raw Russian manes" were being manufactured at the time of each of these deaths. Although the women are designated teazers, they were put to the picking and sorting when necessary. M. B. and E. S. were certainly so engaged at the time of their seizure, and probably H. J. O. also. The importance of this change is obvious. The teazer is not brought into contact with the material until it has been spun into ropes and boiled, while the picker and sorter takes the hair in its raw condition, and shakes out the rougher impurities, while arranging it as to colour and quality. In this way every part of the bale is handled, the operator bending over it. The Messrs. McRae are disposed to regard the sickness and death of M. B. and E. S. as having

"something to do with the hair." They were more particularly struck with the case of E. S., who was a very healthy, steady, well-behaved woman, a good worker, and one of their oldest hands. H. J. O., on the other hand, was a delicate woman, regarded as consumptive.

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Immediately on the death of E. S., they determined to cease the use of Russian hair, which they say can without inconvenience be entirely dispensed with in the trade. There was a small quantity in stock which they boiled in bulk, before handling it, and then worked up without accident.

The factory is much smaller than the Adelphi work, and not well adapted for the purpose. The buildings are old and badly constructed. The machine shed especially is confined, and the arrangements for collecting the dust, and preventing it from impregnating the general atmosphere are rude and insufficient.

Several of the writers quoted who refer to the risks of the manufacture of hair, touch upon the important question of prevention, but excepting in one instance very meagrely. The chief suggestions made are these: Patissier (1) advises that suspected bales should be spread out in the open air, and also treated with sulphur and other acid vapours. The workers who handle it must wash frequently with a mixture of vinegar and water. Ibrelisle (5) says that to purify the hair it ought before manufacture to be boiled with steam, but he very properly remarks that it is a trade question whether this process could be adopted without lowering its commercial value, by impairing its properties of elasticity, &c. He points out that large airy well-ventilated apartments, designed primarily for the business, evidently diminish the risk, as shown by the immunity enjoyed by workers in the trade factories, as compared with the narrated experience of the prisoners who treated the hair in the cells of their prison. Vernois (12) repeats the recommendation to open bales of hair only in the open air, and to ventilate thoroughly the workshops where it is sorted and beaten. Again, under "Crins de Bœuf et de Cheval, soies de Cochon (Preparation des par la Fermentation)," he advises that the store where the bales are kept should have a special ventilating shaft, and that the hands and general cutaneous surface should be carefully inspected to detect the first indications of malignant pustule. Tardieu (13) remarks, that accidents occur much more rarely in workshops which are well ventilated than in those which are not. This, with avoidance of opening the bales in close spaces, and great attention to personal cleanliness on the part of the workers, will suffice to do away with the risk. Bollinger (23) goes to the fountain head of the mischief when he says that the prophylaxis consists essentially in the destruction of all parts of diseased animals, but he adds that the legal enactments prescribed in all civilized countries are very insufficiently enforced and practised. Suitable instruction as to the nature and properties of anthrax should be given to all handicraftsmen who are exposed, and as to the value of the early application of caustic (carbolic acid) to external lesions. The caustic should always be at hand in such works. Proust (25) refers to this matter of "cupidity and carelessness" leading to the clandestine preservation of parts of infected animals. He also states that the activity of the virus is destroyed by a temperature of 60° C., by chlorine water, carbolic acid, and putrefaction. Hirt (24) explains the law of his country on the destruction of diseased animals, but says that all restrictions and attempts at disinfection in regard to foreign hair, &c. imported are worthless.

The report of the Massachusetts State Board of Health on the Walpole outbreak enters fully into the subject of prevention. After a discussion "on the value and application of disinfectants or antiseptics"

in general, the writer states that the facts indicate very clearly the importance of resorting at once to energetic measures of disinfection whenever there is reason to suppose that any infected hair exists in a factory. He then summarizes his suggestions thus:

"I. All suspected hair should be thoroughly disinfected, either by boiling for one half hour or by wetting with a solution of carbolic acid in proportions of two ounces to one gallon of water.

"The former process is the one which has thus far been adopted by the proprietors of the Walpole Factory, from the belief that it would be more efficacious. It has been found, however, that boiling the hair extracts a large proportion of the animal oil contained in it, thereby destroying its elasticity, rendering it more difficult to pick and spin, and causing considerable diminution in the weight.

"It remains, therefore, to be decided whether on the whole the application of the acid is not less expensive and equally efficacious, since the weight of hair is not diminished by its use nor its quality impaired. Furthermore, as the hair is invariably boiled in the latter stages of its manufacture, all odour left by the acid must thereby be removed.

"II. The rooms to which the hair has been admitted should be thoroughly disinfected. The roofs and walls should be washed with lime. The floors and woodwork should be washed with water containing soda, and then sprinkled with a solution of carbolic acid. The clothing, boots, and shoes of the operatives also demand attention, as the seeds of the disease may have attached themselves to some of these articles.

"III. Those who are obliged to handle hair suspected of being infected, should previously anoint their hands with a mixture of carbolic acid and lard, in the proportion of one drachm to the ounce" (p. 107).

We are told that a supply of this ointment is kept constantly at hand in all the departments of Walpole Factory.

The reporter claims for these proceedings the credit of the fact that "since a thorough disinfecting process was adopted, but one mild case of the disease has taken place, although a period of sixteen months has now elapsed."

It is evident, on considering the conditions and circumstances surrounding the propagation of anthrax or charbon by hair in course of manufacture, that by any measure short of the exclusion of the contagium they are of a nature such as to render them extremely difficult if not impossible to be fully met by preventive measures. The dangers of dust as a mechanical irritant, varying in intensity according to its physical nature and properties, are well known, and the precautions to be adopted according to the trade or process in the course of which they arise have been well considered and ought to be observed in hair as in other factories and workshops. The general hygienic arrangements of hair factories ought to be as perfect as they can possibly be made. The apartments ought to be roomy and well ventilated. The dust ought to be prevented from mingling with the general atmosphere, and in the machine room, where the "willowing" and carding processes are carried out, the volatile débris ought, by extracting shafts and fanners, to be collected, and finally destroyed by fire. But we have to cope with more than the mere mechanical properties of ordinary dust. The most dangerous part of hair-dust consists of organised particles, the contagium of a subtle animal poison which does not even require to be inhaled, but may by simple contact with the skin fatally affect the workers. It is almost impossible to imagine precautions sufficient to protect workpeople engaged amongst dust having such properties, still more amongst a material impregnated with particles so subtle and active

as to be dangerous, apart altogether from visible dust. It seems evident therefore, that the only radical and absolutely trustworthy measures for the prevention of such outbreaks among hair-workers are these :—

1. The prevention of the utilization of the hair of infected animals. It is against the law in most countries, if not all, to utilize the carcases of such animals or any part of them, but everyone knows how difficult it is to enforce such laws in the face of cupidity and ignorance, and they certainly can have little practical effect in such countries as Russia and South America. Nevertheless, the knowledge of such grave facts as those now collected and put upon record may enable the governments of this and other countries to make such representations and remonstrances as may lead to more strict supervision of the collection and exportation of hair, and general enforcement of the enactments as to the disposal of diseased animals and their various products or parts.

In view of the pre-eminence of Russian hair as an observed source of infection the question of entirely prohibiting its introduction is suggested. One result of these occurrences in Glasgow is that two at least of the manufacturers have resolved to have nothing more to do with it.

2. Failing such absolute safety as the exclusion of infected hair would provide, the only other radical precaution is to submit all hair in bulk to some process which would disinfect it, *i.e.*, kill the virus which may exist therein, before the hair is disturbed or handled. As pointed out by Dr. Ibrelisle and in the Massachusetts report, this is really a trade question. The possibility of enforcing such a precaution entirely depends upon the effect which such a process would have upon the properties of the hair. At present this Russian hair after carding and spinning is boiled in steam vats for 20 minutes to half an hour, and if dyeing is necessary it is boiled in dyeing before carding, &c., but not before sorting. The question is, could it not all be boiled in bulk? If it could, then no risk would attend its subsequent manipulation. The Massachusetts experience is, however, it is to be feared, enough to decide the impracticability of the suggestion. The Glasgow manufacturers also state that the boiling lowers the value of the hair, and is employed in fact to turn to account the physical effects of the process upon the hair for trade purposes, viz., "to set the curl." Therefore to employ it at a prior stage of the manufacture would introduce this physical change at a time when it would injure the hair, and probably make it useless for the purpose for which it is intended to adapt it.

We are therefore forced to consider what general precautionary measures can be suggested which would palliate a risk which apparently must attend the manufacture of hair. It is very doubtful, from the transient effects which the observations of Dougall have proved carbolic acid to exercise upon the vaccine contagium, whether its application in solution to the hair in bulk, as recommended in the Massachusetts report, would be efficacious. With the restoration of the hair to the dry condition, which must necessarily precede the stage of further manufacture, would come a renewal of the potential activity of the contagium. I am not aware of any other chemical agent which could be applied in sufficient strength to destroy the contagium without exercising its properties upon the organised structure of the hair, so as also to destroy it.

Apart then from any precautions directly operating upon the material, and always supposing the existence of generally good hygienic conditions in the work, and of special provision for the collection, expulsion and destruction of the dusty debris from the machine room, the following palliative suggestions may be mentioned :—

1. To prevent poisoning by inhalation, respirators ought to be worn by the hands employed in the machine room, in the spinning room, also in the sorting department. It is, however, a matter of experience that workpeople will not use this simple precaution. The laying aside of respirators on every convenient opportunity, like the unlocking of Davy lamps, would undoubtedly be practised.

2. To prevent poisoning by external contact, bare arms should be prohibited, and close-fitting, high-necked, long-sleeved over-garments of some close texture should be enforced, possibly supplied, left in the works, and regularly cleansed. The application of carbolic lard to the necessarily exposed surfaces, *e.g.*, of the hands and face, as suggested in the Massachusetts report, is to be recommended. But from the well-known drying and injurious effect of carbolic acid upon the skin, females would object to use it. Therefore simple lard or camphorated oil would be preferable. Above all things, strict personal cleanliness should be observed. The free use of soap and water applied to the face and arms at each meal hour, and at the close of work would be eminently useful. Ample facilities in the shape of lavatories supplied with all requisites ought to be provided in the work.

No person having any open sore on their person, or having fissures, or any other cutaneous lesion should be employed.

3. To prevent poisoning by deglutition, no eating or drinking within the work or keeping of food on the person or about the factory ought to be allowed. A room for this purpose should be provided, remote from the workrooms, and beyond the possibility of access of dust.

4. Every means ought to be adopted to inform the workers of the risks attendant upon their employment, and of the nature of the contagion to which they are exposed. Caustic in some convenient form ought always to be at hand, ready for immediate application to any suspicious pimple.

P.S.—Since writing the foregoing report, another instance of infection from hair, again of Russian origin, has come under my notice. Two cases of external anthrax on the left side of the neck, in the persons of girls employed in picking and sorting Russian manes in Govan hair works were admitted in July to the Western Infirmary, under the care of Dr. McCall Anderson. A clinical description of these cases will be found in the "Glasgow Medical Journal" for September 1879. It is there stated that a specimen of the blood was examined by Dr. Coats. In one case "At first nothing abnormal was observed on microscopical "examination, but in the course of a day or two, numerous motionless "rod-like bodies were found in the preserved specimen. In the second "case, * * * nothing abnormal was observed, either when the blood was "newly drawn, or four days after." (p. 215). Very probably, had the local extravascular fluids been examined, the *bacillus anthracis* would have been demonstrated at once. Two other girls, both employed in the spinning department, were contemporaneously attacked with severe vomiting and colicky pains in the bowels, but recovered speedily. The Govan hair works are of modern construction, and are airy and well ventilated. Judging from the raw manes which were being sorted at the time of my visit, the quality was very inferior. The material was a mixture of cow and horse hair, charged with impurities of various kinds, both animal and vegetable.

11th September, 1879.

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No. 8.

General Memorandum on the Proceedings which are advisable in Places attacked or threatened by Epidemic Disease.

1. Wherever there is prevalence or threatening of cholera, diphtheria, fever, or any other epidemic disease, it is of more than common importance that the statutory powers conferred upon Sanitary Authorities for the protection of the public health should be well exercised by those Authorities, acting with the advice of their Medical Officers of Health.

2. Proper precautions are equally requisite for all classes of society. But it is chiefly with regard to the poorer population, therefore chiefly in the courts and alleys of towns, and at the labourers' cottages of country districts, that local authorities are called upon to exercise vigilance, and to proffer information and advice. Common lodging-houses, and houses which are sub-let in several small holdings, always require particular attention.

3. Wherever there is accumulation, stink, or soakage, of house refuse, or of other decaying animal or vegetable matter, the nuisance should as promptly as possible be abated, and precaution should be taken not to let it recur. Especially examination should be made as to the efficient working of sewers and drains, and any nuisance therefrom, or from any foul ditches or ponds, should be got rid of without delay. The ventilation of sewers, the ventilation and trapping of house drains, and the disconnection of cistern overflows and sink pipes from drains should be carefully seen to. The scavenging of the district, the state of receptacles for excrement, and of dust-bins, will require particular and sustained attention. In slaughter-houses, and wherever animals are kept, strict cleanliness should be enforced.

4. In order to guard against the harm which sometimes arises from disturbing heaps of offensive matter, it is often necessary to combine the use of chemical disinfectants (*see* § 17) with such means as are taken for the removal of filth; and in cases where removal is for the time impossible or inexpedient, the filth should always be disinfected. Disinfection is likewise desirable for unpaved earth close to dwellings, if it be sodden with slops and filth. Generally, where cholera or enteric (typhoid) fever is in a house, the privy requires to be disinfected.

5. Sources of water-supply should be well examined. Those which are in any way tainted by animal or vegetable refuse, above all, those into which there is any leakage or filtration from sewers, drains, cesspools, or foul ditches, ought no longer to be drunk from. Especially where the disease is cholera, diarrhœa, or enteric fever, it is essential that no foul water be drunk.

If unfortunately the only water which for a time can be got should be open to suspicion of dangerous organic impurity, it ought at least to be boiled before it is used for drinking, but then not to be drunk later than twenty-four hours after it has been boiled. Or, under medical or other skilled direction, water, in quantities sufficient for one day's drinking in the house, may be disinfected by a very careful use of Condy's red disinfectant fluid; which should be added to the water (with stirring or shaking) in such number of drops that the water, an hour afterwards, shall have the faintest pink colour which the eye can distinctly perceive. Filtering of the ordinary kind cannot by itself be trusted to purify, but it is a good addition to either of the above processes. It cannot be too distinctly understood, that dangerous qualities of water are not obviated by the addition of wine or spirits.

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When there appears any probable relation between the distribution of disease and of milk supplies, the cleanliness of dairies, and the purity of the water used in them, should be carefully investigated.

6. The washing and lime-whiting of uncleanly premises, especially of such as are densely occupied, should be pressed with all practicable despatch.

7. Overcrowding should be prevented. Especially where disease has begun, the sick-room should, as far as possible, be free from persons who are not of use or comfort to the patient.

8. Ample ventilation should be enforced. It should be seen that window-frames are made to open and that windows are sufficiently opened. Especially where any kind of infective fever has begun, it is essential, both for patients and for persons who are about them, that the sick-room and the sick-house be constantly well traversed by streams of fresh air.

9. The cleanliest domestic habits should be enjoined. Refuse matters which have to be cast away should never be allowed to remain within doors; and things which have to be disinfected or cleansed, should always be disinfected or cleansed without delay.

10. Special precautions of cleanliness and disinfection are necessary with regard to infective matters discharged from the bodies of the sick. Among discharges which it is proper to treat as infective, are those which come, in cases of small-pox, from the affected skin; in cases of cholera and enteric fever, from the intestinal canal; in cases of diphtheria, from the nose and throat; likewise, in cases of any eruptive or other epidemic fever, the general exhalations of the sick. The caution which is necessary with regard to such matters must, of course, extend to whatever is imbued with them; so that bedding, clothing, towels, and other articles, which have been in use by the sick, may not become sources of mischief, either in the house to which they belong, or in houses to which they are conveyed. Moreover, in enteric fever and cholera, the evacuations should be regarded as capable of communicating an infectious quality to any night-soil with which they are mingled in privies, drains, or cesspools; and this danger is best guarded against by thoroughly disinfecting them before they are thrown away (*see* § 17); above all, they must never be cast where they can run or soak into sources of drinking water.

11. All reasonable care should be taken not to allow infective disease to spread by the unnecessary association of sick with healthy persons. This care is requisite, not only with regard to the sick-house, but likewise with regard to day schools and other establishments wherein members of many different households are accustomed to meet.

12. Where dangerous conditions of residence cannot be promptly remedied, it will be best that inmates, while unattacked by disease, remove to some safer lodging. If disease begins in houses where the sick person cannot be rightly circumstanced and tended, medical advice should be taken as to the propriety of removing him to an infirmary or hospital. Every sanitary authority should have in readiness a hospital for the reception of such cases.

13. Privation, as predisposing to disease, may require special measures of relief.

14. In certain case special medical arrangements are necessary. For instance, as cholera in this country almost always begins somewhat gradually in the comparatively tractable form of what is called "premonitory diarrhœa," it is essential that, where cholera is epidemic, arrangements should be made for affording medical relief without delay to persons attacked, even slightly, with looseness of bowels. So again,

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where small-pox is the prevailing disease, it is essential that all unvaccinated persons (unless they previously have had small-pox) should very promptly be vaccinated; and that re-vaccination should be performed in cases properly requiring it.

15. It is always to be desired that the people should, as far as possible, know what real precautions they can take against the disease which threatens them, what vigilance is needful with regard to its early symptoms, and what (if any) special arrangements have been made for giving medical assistance within the district. For the purpose of such information printed hand-bills or placards may usefully be employed, and in cases where danger is great, house-to-house visitation by discreet and competent persons may be of the utmost service, both in quieting unreasonable alarm, and in leading or assisting the less educated and the destitute parts of the population to do what is needful for safety.

16. The present memorandum relates to occasions of emergency. Therefore the measures suggested in it are all of an extemporaneous kind; and permanent provisions for securing the public health have not been in express terms insisted on. It is to be remembered, however, that in proportion as a district is habitually well cared for by its sanitary authorities, the more formidable emergencies of epidemic disease are not likely to arise in it.

17. Chemical disinfectants are of two great classes, and hitherto it is not certain which of the two classes acts best. The one class is well represented by chlorine and certain of its compounds; the other is well represented by carbolic acid. Under the former system, the solution of chloride of lime may be used for minor domestic purposes, chloride of lime itself to any masses of filth, and chlorine gas for disinfection of rooms. Under the latter system carbolic acid may be used for minor domestic purposes, sulphate or perchloride of iron to any masses of filth, and sulphurous acid gas for disinfection of rooms. These systems do not combine well with one another, and in the choice which has to be made between them, it will be convenient that the sanitary authority of each district should declare which of the two systems it adopts, and that all private disinfection in the district shouid follow such lead of the authority. The detail in each case should be carried out under medical advice. In public disinfection-establishments for the disinfection of wearing apparel, bedding, curtains, and other large household articles, the most convenient process consists in employment of high degrees of heat.

18. For detailed advice on Hospital Accommodation and on Ambulances, see the Office Memoranda on those subjects.

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